Graeco-Arabic Astronomy for Twelfth-Century Latin Readers

Time, Astronomy, and Calendars

TEXTS AND STUDIES

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Graeco-Arabic Astronomy for Twelfth-Century Latin Readers

Ptolomeus et multi sapientum (Abraham Ibn Ezra Latinus) — Robert of Chester, *Liber canonum*, pt. II

By

C. Philipp E. Nothaft

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Preface

No account of the history of science in medieval Europe would be complete without reference to Ptolemy's *Almagest*, whose rendering into Latin during the twelfth century has been called "the most significant event in the history of astronomical translation" as well as "[t]he greatest astronomical event in Western Christendom."[1] It is not difficult to see how a judgment of this magnitude might be justified. To this day, the *Almagest* remains our single most important source for tracing the historical development of Hellenistic astronomy, which resulted from a fusion between Babylonian traditions of observation and computation and Greek approaches to the geometrical modelling of celestial motions.[2] Just as significantly, Ptolemy's work offers us the earliest surviving account of how to select and utilize observational data in the creation of predictively viable theories of planetary motion. A general characteristic of these theories is that they apply precise numerical parameters to kinematic models constructed from geometrical devices, which can in turn be translated into user-friendly numerical tables for the efficient computation of planetary positions as a function of time.

While the twelfth-century introduction of the *Almagest* was clearly a momentous event, historians have long understood that the revival of Hellenistic astronomy in medieval Europe cannot be reduced to a single act of translation. For one thing, the availability in early medieval libraries of certain Roman encyclopaedic texts—Pliny, Macrobius, Martianus Capella, Calcidius—had ensured that Latin readers around 1100 were already familiar with a range of theoretical ideas that feature prominently in the *Almagest*, from the spherical model of the universe to the basic concept of eccentric deferents and epicycles.[3] Even without full access to Ptolemy's sophisticated geometrical models, moreover, early medieval Latin Europeans are known to have engaged in different forms of astronomical computation. One avenue for this practice was provided by *computus*, a discipline originally geared toward computing the date of Easter as well as other ecclesiastical feast days. Over time, the arithmetical techniques developed within this discipline found applications outside of the immediate calendrical context, for instance in addressing ecliptic longitudes of the Sun and Moon as well as the occurrence of eclipses.[4] While the astronomical remit of *computus* remained narrowly lunisolar, early medieval manuscripts also preserve arithmetical rules that made it possible to find the zodiacal positions of the five planets as a function of the current year since the Creation. In combination with some rudimentary rules for establishing the ascending sign, these algorithms provided a basis for drawing up horoscopes, long before the Arabic-to-Latin translations of the twelfth century granted access to much more advanced astrological techniques.[5]

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[1] The two quotes are taken from Pedersen (Olaf) 1978: 313, and Sarton 1927–1948: ii. 297 (repeated nearly verbatim on p. 403). Southern (1953: 64) similarly referred to the translation of the *Almagest* as "[o]ne of the most important events in the history of the [*sic*] twelfth-century scientific thought." For bibliographical information on the three surviving Latin *Almagest* translations that were made during the twelfth century, see David Juste, "Ptolemy, *Almagesti* (tr. Gerard of Cremona)" (update: 21.04.2022), *Ptolemaeus Arabus et Latinus. Works*, URL = http://ptolemaeus.badw.de/work/3; idem, "Ptolemy, *Almagesti* (tr. Sicily c. 1150)" (update: 21.04.2022), *Ptolemaeus Arabus et Latinus. Works*, URL = http://ptolemaeus.badw.de/work/21; idem "Ptolemy, *Almagesti* (tr. ʿAbd al-Masīḥ of Winchester)" (update: 21.04.2022), *Ptolemaeus Arabus et Latinus. Works*, URL = http://ptolemaeus.badw.de/work/22.

[2] On Hellenistic astronomy, see Bowen and Rochberg 2020.

Another important point to make is that the transfer of Hellenistic mathematical astronomy to Latin Europe via Arabic channels was a relatively drawn-out process that was not firmly tied to the transmission history of the *Almagest*. It already commenced in the late tenth century with the Catalonian creation of a so-called 'Old Corpus' of texts on the astrolabe and other horological instruments, which played a significant role in furthering a Latin audience's understanding of celestial geometry.[6] More significant in the long run were the translation activities that unfolded on the Iberian peninsula during the first half of the twelfth century, which saw scholars such as Plato of Tivoli, John of Seville, Hermann of Carinthia, and Hugo Sanctelliensis make available a rich body of technical Arabic writings on both astronomy and astrology, including computational tables. By the early 1150s, when Gerard of Cremona was still busy working in Toledo on his famed *Almagest* translation, a substantial range of Graeco-Arabic astronomical writing had thus already made its way into Latin.[7]

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[3] The two key publications on early medieval Latin astronomy are McCluskey 1998; Eastwood 2007.

[4] For recent studies and discussions of these aspects of *computus*, see Warntjes 2016; 2020; Nothaft 2017c: 18–31, 36–46; 2018c: 42–79.

[5] Juste 2020.

[6] See, e.g., Millás Vallicrosa 1931; Wiesenbach 1991; Borrelli 2008; Samsó 2004a; 2004b; 2020: 378–399; Jacquemard 2015; Juste 2016.

[7] On the twelfth-century 'translation movement' in Spain, see Lemay 1963; Millás Vallicrosa 1963; Hourani 1972; Burnett 1977; 1992; 2001; 2014; Pizzamiglio 1992; Hasse 2006; Lejbowicz 2009; Mantas-España 2014; Samsó 2020: 20–33. Geographically broader accounts of high-medieval scientific translations into Latin are offered in Haskins 1924; Lindberg 1978: 62–79;

While many of these sources were rooted firmly in the astronomical tradition established by Ptolemy's *Almagest* and *Handy Tables*, some reflected the admixture of a non-Ptolemaic, Indian strand of Hellenistic astronomy, whose presence in Muslim Spain had been mediated by the ninth-century *Sindhind Zīj* of al-Khwārizmī.[8]

The treatises and numerical tables that newly entered the Latin Christian cultural sphere at this time were liable to pose steep intellectual challenges to their recipients, insofar as they often presupposed a degree of familiarity with the concepts and methods of mathematical astronomy. Latin readers' interest in predicting celestial configurations in the manner of the Greeks and Arabs would accordingly have fuelled a demand for literature that provided a smoother introduction to the discipline and its technical subtleties than was typically offered by straightforward translations of works such as al-Battānī's *Ṣābiʾ Zīj* (*c.* 900). An important aspect of the reception of Hellenistic astronomy in twelfth-century Europe hence consisted in the production of Latin texts that, rather than being derived directly from Arabic, were original compositions aimed at a Latin Christian readership. Works of this kind typically sought to offer a simplified pathway into mathematical astronomy, for instance by explaining technical concepts that Arabic or Greek sources took for granted, or by describing the construction and use of computational tables in ways that did not exceed a certain level of mathematical skill or training.

The core purpose of the present volume is to make available two hitherto unpublished astronomical texts that can be counted among the earliest known entries in this broader genre. They were written towards the end of the first half of the twelfth century—in *c.* 1145 and *c.* 1150—with the goal of turning their readers into competent users of astronomical computational tables in, broadly speaking, the Ptolemaic tradition. Aside from their chronological proximity, the two texts are connected through the specific sets of tables their authors sought to elucidate, their meridians of reference being those of Pisa and London. As Raymond Mercier was the first to demonstrate more than three decades ago,[9] the mean-motion tables computed in the twelfth century for these two locations were variants of each other that ultimately depended on the same source: a lost Eastern Arabic *zīj* attributed to the Persian astronomer Abd al-

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Alverny 1982; Burnett 1985; 2013; 2022; Montgomery 2000: 138–185; Brentjes 2000. For some facts and figures concerning translations of astronomical and astrological texts into Latin, see Burnett and Juste 2016.

[8] For a comprehensive survey of Islamic astronomy in medieval Iberia and North Africa, see Samsó 2020. On the Indian influence, see Pingree 1996; Chabás and Goldstein 2015.

[9] Mercier 1991.

Rahman al-Ṣūfī (903–986). This *zīj* stands apart from any of the other sets of computational tables that circulated in Latin Europe during the twelfth century in having been imported, not from Iberia or Sicily, but directly from the East (Mashriq) itself, apparently owing to existing trade connections between Italy (Pisa) and the Crusader States (Antioch).

The volume is divided into two parts, each of which is very much intended to stand alone. Part 1 deals with an anonymous and untitled treatise beginning *Ptolomeus et multi sapientum,* whose three main sections introduced readers to the following broader areas of computational astronomy: (i) precession and the length of the solar year; (ii) the construction of mean-motion tables; and (iii) the Ptolemaic planetary models and the computation of true longitudes. *Ptolomeus* is known from only two manuscripts, neither of which appears to preserve the text in its entirety. Nevertheless, the over 16,500 words that survive make *Ptolomeus* a candidate for the most extensive twelfth-century Latin work on mathematical astronomy to have never been printed until now. As I shall argue in some detail in the introduction to Part 1, the text shows multiple and compelling signs of belonging to a large corpus of astronomical and astrological writings that were created during the middle decades of the twelfth century by Abraham Ibn Ezra, the influential Jewish scholar and poet, on his documented journeys through Italy, France, and England. While most of these writings were original compositions in Hebrew, the specific scenario that suggests itself for *Ptolomeus* is that Ibn Ezra created it by dictating it to an unknown Christian collaborator, who was responsible for its Latin form.

A somewhat simpler case in terms of attribution is the *Liber canonum* by Robert of Chester, which is the subject of Part 2 of this volume. As with *Ptolomeus*, the state of transmission of the *Liber canonum* is less than pristine, inasmuch as the known manuscripts preserve only the second of what were originally two parts. In this second part, which appears to date from around 1150, Robert seeks to explain the use of a collection of tables for the coordinates of London, which were in part an adaptation of the Tables of Pisa that had previously been discussed in *Ptolomeus*. Robert, a well-known translator of scientific Arabic texts, shows no awareness of this connection and instead associates his tables with the work of al-Battānī, whose precession value and apogeal longitudes have indeed left certain traces within the Tables of London. There is some indication, moreover, that Robert availed himself of a Latin adaptation of the so-called Toledan Tables, which appears to have been structurally similar to the Tables of Marseilles adapted in *c.* 1141 by Raymond of Marseilles. Compared to most of the available 'canons' or sets of rules for astronomical tables, which were usually highly concise, Robert of Chester took into account the didactic needs of his audience and therefore offered an in-depth treatment of essential skills such as calendrical conversions, which were indispensable for a competent use of planetary mean-motion tables.

Both texts, *Ptolomeus et multi sapientum* and the *Liber canonum* (pt. II), are reproduced below as critical editions with facing English translations. Each edition is preceded by a sequence of introductory chapters, which set out what can be ascertained about the text's authorship, sources, transmission, and later reception. In addition, each introduction will deal in some detail with the set(s) of astronomical tables that originally underlay the work in question. As for the technical content of each text, it will be treated in more detail in a section-by-section commentary attached to the relevant edition/translation. Both editions are complemented by an appendix, which in the case of Part 1 is there to document some otherwise unattested astronomical material that is transmitted adjacent to *Ptolomeus et multi sapientum* in one of the two manuscripts. Included among these textual items is what appears to be a hitherto unknown Latin translation of some canons for the *Sindhind Zīj* of al-Khwārizmī, which may refer to the lost original version of this *zīj* rather than the tenth-century Andalusian recension by Maslama al-Majrīṭī. The appendix in Part 2 reproduces some textual additions to the *Liber canonum* that are likely to be extraneous to the original work.

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Abbreviations and Manuscript Sigla

A	Oxford, Bodleian Library, Ashmole 361
C	Cambridge, Fitzwilliam Museum, McClean 165
C_2	Cambridge, University Library, Add. 6866
D	Oxford, Bodleian Library, Digby 114
K	København, Det Kongelige Bibliotek, GkS 277 2°
L	London, British Library, Arundel 377
LRT	Abraham Ibn Ezra, *Liber de rationibus tabularum* (ed. in Millás Vallicrosa 1947: 73–167).
M	Madrid, Biblioteca Nacional de España, 10016
N	Napoli, Biblioteca nazionale 'Vittorio Emanuele III', VIII.C.49
O	Oxford, Bodleian Library, Selden supra 26
O_2	Oxford, Bodleian Library, Selden supra 90
ʿOlam III	Abraham Ibn Ezra, *Sefer ha-ʿOlam*, third version, translated into Latin by Henry Bate (ed. by Carlos Steel in Steel, Sela, Nothaft, Juste, and Burnett 2020: 244–256).
P	Paris, Bibliothèque nationale de France, lat. 16208
S	Oxford, Bodleian Library, Savile 21
S_2	Oxford, Bodleian Library, Savile 25
T	Toledo, Archivo y Biblioteca Capítulares, 98–22
V	Città del Vaticano, Biblioteca Apostolica Vaticana, Vat. lat. 3119

PART 1

Ptolomeus et multi sapientum

⁂

Introduction

The Latin text to be edited and analysed below is an anonymously transmitted work from *c.* 1145 beginning with the words *Ptolomeus et multi sapientum*. I shall refer to it simply as *Ptolomeus* for the remainder of this study. In its preserved form, the text consists of three distinct sections or parts, each covering a substantial aspect of mathematical astronomy in the Ptolemaic or Graeco-Arabic tradition, to wit: (i) the length of the solar year and the phenomenon of precession; (ii) the construction of tables of planetary mean motion; (iii) the Ptolemaic planetary models and the resulting tables for equations, stations/retrogradations, and latitudes. Each of these parts confronted twelfth-century readers with a range of technical concepts that were unfamiliar from the perspective of traditional Latin learning. If this is one good reason to make *Ptolomeus* available in a critical edition, a further one stems from the strong possibility that its author was none other than Abraham Ibn Ezra, the influential Jewish exegete, poet, mathematician, and astrologer. I shall explore this question in some detail below (see §§ 2–3), where I argue that *Ptolomeus* must indeed be included in the corpus of Ibn Ezra's Latin works.

Ptolomeus is transmitted in two manuscripts from the decades around 1200 (see § 5). One of these, *O* = Oxford, Bodleian Library, Selden supra 26, covers extended portions of pts. II and III but lacks of all pt. I. It is at least doubtful that the fuller version known from the second manuscript, *C* = Cambridge, Fitzwilliam Museum, McClean 165, represents the complete text as originally conceived. While the codex in question is relatively well known to scholars, its rendition of *Ptolomeus* has only rarely been the subject of scholarly commentary. Perhaps the earliest significant discussion is contained in an unpublished doctoral thesis by Joshua Lipton (1978), who briefly and accurately remarked on the "many clear resemblances" between this text and Abraham Ibn Ezra's Latin *Liber de rationibus tabularum* (hereafter cited as LRT).[1] Since the end of *Ptolomeus* is not clearly marked in *C*, Lipton assumed that he could use a reference to year 557 of the Hijri era (= AD 1161/62) on fol. 76^v to assign a date of 1161. He accordingly surmised that *Ptolomeus* may be a later redaction of the LRT, which is known to date from 1154.[2] I shall argue below (§ 5) that the text of *Ptolomeus* already breaks off on fol. 75^v and that its actual year of composition was 1145 (see § 1), putting it nearly a decade before the LRT.

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[1] Lipton 1978: 159.

[2] Lipton 1978: 159, 190 (n. 24).

Another scholar who has highlighted similarities between *Ptolomeus* and the LRT is Raymond Mercier. In two articles first published in 1987 and 1991, he showed that the astronomical mean-motion tables on which the author of *Ptolomeus* relied were identical with the Tables of Pisa composed or compiled by Ibn Ezra.[3] Mercier took a rather dim view of the text, stating (without providing further details) that it contains "signs of a poor grasp of technicalities, and substantial errors of fact."[4] He also argued categorically against Ibn Ezra's authorship, pointing to the occurrence of the phrase "our Lord Jesus Christ" (*domini Ihesu Christi*) on fol. 67^{r}.[5]

Since the appearance of Mercier's publications, little of substance has been written about the text or the question of its authorship. The two most significant contributions have come from Fritz S. Pedersen (1990) and Charles Burnett (2002), who both noticed the existence of a second, partial copy in *O*. Burnett drew attention to *O*'s use of Hindu-Arabic numerals in their Eastern rather than the conventional Western form, which is a trait it shares with several Latin manuscripts containing works by Abraham Ibn Ezra or otherwise connected to his Tables of Pisa.[6] Pedersen made the important observation that *Ptolomeus*'s lunar model implies an inversion of the standard Ptolemaic model and tentatively suggested that it may therefore be related to another twelfth-century treatise with the incipit *Investigantibus astronomiam primo sciendum …*, which also inverts the model.[7] As I shall argue below (pp. 165–168), the similarities between these texts are in fact too superficial to establish any line of influence.

The most recent scholar to comment on the question of *Ptolomeus*'s authorship is Shlomo Sela (2020), who argues that the formula *anni domini nostri Ihesu Christi*, as used in the text, "could not have been possibly used by a Jew." He accordingly rejects the idea that either this text or the LRT "could have been written by Abraham Ibn Ezra himself."[8] I shall re-visit this question in § 3 below, where I draw the conclusion that *Ptolomeus* is best explained as the outcome of a collaboration between Ibn Ezra and a Christian scribe.[9] Other sections of the present introduction will deal with the astronomical tables presupposed in this text (§ 2), its vocabulary and other general characteristics

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[3] Mercier 1987: 110–111; 1991: 15–16.

[4] Mercier 1991: 15.

[5] Mercier 1987: 111; 1991: 15.

[6] Burnett 2002a: 251. See also n. 87 below.

[7] Pedersen 1990: 211–212, 214–216.

[8] Sela 2020: 12.

[9] See previously already Nothaft 2018b: 155, where I note the possibility that that "*Ptolomeus* was the product of a Christian student or collaborator of Ibn Ezra, who presented the Jewish master's doctrine in his own words."

(§ 1), its later reception (§ 4), and its manuscript transmission (§ 5). The edition itself will be accompanied by an English translation and a section-by-section commentary that addresses noteworthy aspects of the content, justifies textual emendations, and notes parallels to other writings by Ibn Ezra. An appendix will describe the astronomical texts and fragments that follow immediately upon *Ptolomeus* in manuscript *C*.

1 General Characteristics

At first approximation, *Ptolomeus* may be described as a detailed effort to convey to an astronomically untrained audience the theoretical and operational principles behind computational tables for planetary longitudes, with some added information on latitudes. In fact, much of the text doubles as an exposition of a specific set of tables for mean motions and equations (see § 2), which the author notes were constructed in AD 1143 (pt. II, l. 14). In a passage that instructs readers on how to adapt these tables to a starting epoch of their own choosing, he uses the example of "1144 completed past years" (l. 271: *1144 completis annis preteritis*). Taking these 1144 completed years as a starting point, the text in manuscript *O* (fol. 126^{r}) orders us to "begin the present year from the first noon of the immediately preceding March" (ll. 271–272: *ab eodem presentem annum incipe a prima meridie Martii proximi preteriti*).[10] It seems plausible that the "present year" was here chosen to reflect the author's own year of writing, in which case *Ptolomeus* would be datable to 1145.[11]

Although the text was written with a particular set of astronomical tables in mind, its content is not confined to presenting 'canons' or rules for their use. Rather, the author intended to familiarize readers with the theories of planetary motion that are implicit in these rules and to account for the specific ways in which the tables themselves are constructed. One of the implicit goals of pt. I is to provide a better understanding of the signs and degrees that are recorded in the mean-motion tables introduced later in pt. II. Since the tables in question are based on a tropical year, the signs must be read as tropical signs counted from the vernal point. To ensure they are able to appreciate this point, readers are offered an account of how the phenomenon of precession—which here as elsewhere in medieval astronomy is explained as a slow motion of the sphere of fixed stars—necessitates two separate definitions of the solar year as well as two reference frames for tracking ecliptic longitudes, viz. tropical and sidereal (see I.i–ii). It also goes into some detail on how the Julian year ordinarily used by Latin Christians is different from either type of year, causing the dates of the Sun's entries into the tropical and sidereal signs to shift over time (I.iii). The author concludes pt. I with an informative historical account of how the length of the tropical year assumed in his own mean-motion tables (approximately 365 ¼ – 1/131 days) was the outcome of measurements made by different astronomers across multiple centuries. Astronomy is here effectively depicted as a heavily empirical discipline, in which parameters are extracted through observations separated by long intervals, leading to increased accuracy and, hence, progress over time (I.v).

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[10] In *C* (fol. 70^{r}), the passage reads "utpote a 1144 completis ante presentem annum. Incepit autem prima meridie Martii proximi preteriti."

[11] See previously already Nothaft 2018b: 154. According to Pedersen (1990: 212), the text was composed "after 1144/5." In Mercier 1987: 111, the number 1144 is misread or mistyped as 1149. He is followed by Smithuis 2006: 33.

The discussion of the length of the tropical year at the end of pt. I sets the stage for the detailed explanation of the mean-motion tables in pt. II. Our text teaches how such tables can be constructed from first principles, using as its guiding example the tables for the mean Sun. The process of casting these tables begins with the empirical determination of the length of the tropical year (II.i), which is subsequently converted to yield the Sun's mean motion per day (II.ii). The other data point that requires empirical measurement is the starting value (or *radix*) of the table for collected years, which is established in a laborious arithmetical process beginning with an observation of the time of the vernal equinox (II.iii).

The task of deriving the mean solar longitude from an observed true longitude already involves the use of equation tables, which receive further elucidation in pt. III, by far the lengthiest part of *Ptolomeus*. Besides informing readers about the rules by which equation tables are to be entered and used, this part of the text also seeks to convey an understanding of the underlying astronomical realities. To this end, it includes separate sections describing the Ptolemaic models for the Sun (III.i), Moon (III.ii), and Saturn (III.iii), which is here treated as representative of all five planets. Each of these three accounts was originally accompanied by a geometrical diagram, although all that is left in the two available manuscripts is one defective rendition of the diagram for the Sun (*C*, fol. 71^r). Further sections in pt. III are concerned with the synodic periods of the planets (III.iv), their stations and retrogradations (III.v), and their motions in latitude (III.vi).

Since the descriptions of planetary models in pt. III were intended primarily as commentaries on the corresponding equation tables, the author could feel justified in neglecting certain details. One of the more striking omission concerns the equant point in the models for the five planets, which does not play an explicit role in the rules for calculating a planet's equation from the relevant tables. The text as we have it also has little to say about the kinematic differences between the superior (Saturn, Jupiter, and Mars) and inferior planets (Venus and Mercury) and is entirely silent on the features that set Ptolemy's model for Mercury, with its rotating line of apsides, apart from the remaining planets. While none of these examples imply an intentional departure from conventional astronomical theory, *Ptolomeus* does go against Ptolemaic orthodoxy in describing the different motions of the Moon. According to the account in pt. III.ii, the Moon's first anomaly is the result of its motion on an eccentric deferent with rotating apogee, whereas the second anomaly (i.e., the anomaly that depends on the Moon's position with respect to the Sun) is a consequence of its epicycle. This amounts to an outright inversion of the components that make up Ptolemy's second lunar model.

Overall, there are few, if any, signs that the author drew on the existing Latin astronomical literature when composing his treatise. *Ptolomeus*'s degree of independence with respect to this body of literature is reflected by its technical vocabulary, which rarely coincides with the terms already in circulation by the middle of the twelfth century. For example, it appears to be the only known Latin source to employ the phrase *iunctura circulorum* to refer to the equinoctial points, or to use *annus iuncture* in the sense of 'tropical year'. Its preferred term for 'equation' is *directio*, with *locus directus* denoting a planet's true position. The use of *directio* to render the Arabic *taʿdīl* (تعديل) and, by extension, the Greek προσθαφαίρεσις was apparently first introduced by Petrus Alfonsi when translating the astronomical tables of al-Khwārizmī (*c.* 1116).[12] It did not become the standard expression in Latin astronomy, however, losing out in this respect to *aequatio*.[13]

Another noteworthy aspect of *Ptolomeus*'s vocabulary is its consistent use of *pars* to denote the so-called 'argument' or 'anomaly' of a planet. When writing about the Moon, our author introduces this term as denoting the half or 'part' of the deferent in which the Moon is located with respect to the line of apsides (pt. III, ll. 235–239, 272–275). Even though this definition links the term *pars* with the Moon's motion along the deferent, which is a consequence of the aforementioned inversion of the Ptolemaic model, the author subsequently applies the same term to the epicyclic anomaly of the planets. One can find a partial parallel to this in one of the three sets of canons that accompanied the Toledan Tables in Latin, namely, the set beginning *Scito quod annus lunaris* … (canons 'Ca' in the classification established by F.S. Pedersen).[14] The text in question was commonly attributed to Azarquiel (Ibn al-Zarqālluh) in medieval manuscripts and appears to be an Arabic-to-Latin translation, possibly made by John of Seville in the 1120s or 1130s.[15] It employs *pars* only in connection with the lunar anomaly, but switches to *portio* when discussing the other planets.[16] One may also note that *Ptolomeus* is consistent in using *punctus* to refer to the epicyclic centre of any of the planets, including the Moon. The aforementioned Toledan canons again restrict this term to the Moon and opt for *cuspis* when referring to the centre of any of the five planets.[17]

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[12] See Neugebauer 1962b: 184–205, and the discussion of these tables in Casulleras 1996.

[13] For a survey of the technical vocabulary used in twelfth-century Latin texts, which also draws some examples from *Ptolomeus*, see Poulle 1987.

The corpus of Latin astronomical texts written before 1200 offers us only two other works whose technical vocabulary shows a noteworthy degree of similarity with that deployed in our text: Abraham Ibn Ezra's LRT and the related *Tractatus magistri Habrahe de tabulis planetarum* (see § 2).[18] Both texts mirror *Ptolomeus*'s preference for *locus altus* when speaking about a planet's apogee, although their term for the perigee is *locus humilis* rather than *locus imus* or any of the synonyms used in *Ptolomeus*. They employ *equatio* or *coequatio* rather than *directio* to refer to the equation and uniformly opt for *portio* rather than *pars* to denote 'anomaly'. At the same time, they agree with *Ptolomeus* in their consistent use of *punctus* for the epicyclic centre. In speaking of the diameter-increment of the planetary epicycles, they employ *remotio longiquior* and *propinquior*, which is not far removed from *Ptolomeus*'s standard expression *remotio longior* and *propior*. Their shared expression *remotio duplicata* for the double elongation of the Moon is again similar to *Ptolomeus*'s use of *dupla remotio*. Finally, it seems significant that *Ptolomeus*'s brief section on latitudes (III.vi; see p. 176) uses *dexter* and *sinister* to refer to the northern and southern sections of a planet's inclined circular path, which is a feature it has in common with the LRT, the *Tractatus magistri Habrahe*, and a thirteenth-century Latin translation of the third version of Ibn Ezra's *Sefer ha-ʿOlam* (*ʿOlam* III, § 1:1.8, p. 244).

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[14] The text is introduced, edited, and translated into English in Pedersen (Fritz) 2002: i. 191–323.

[15] On the possibility of attributing this translation to John of Seville, see Hasse 2016: 29–31.

[16] See Ca92–102 in Pedersen (Fritz) 2002: i. 256–262, and the remarks in Nothaft 2018b: 168. The expression *aequatio partis lunae* also appears in Cc239 in Pedersen (Fritz) 2002: ii. 688.

[17] See Ca97 in Pedersen (Fritz) 2002: i. 260.

[18] For comparative tables of the vocabulary used in Abraham Ibn Ezra's Latin corpus, see Smithuis 2004: 207–208; 2006: 58–59.

2 The Tables of Pisa/Lucca

Even though neither manuscript places *Ptolomeus* in the company of any tables, it is clear from the text itself that it was written to elucidate a specific set, to which the author refers as 'my' or 'our tables' (*tabule nostre*, see pt. I, ll. 242, 251; pt. II, ll. 248, 266, 373). His statements reveal that the tables in question were based on an earlier work by the Persian astronomer Abd al-Rahman al-Ṣūfī (903–986), which he recast for a different calendrical format. Al-Ṣūfī's original tables, which are lost, used the Islamic calendar and Hijri era to display planetary mean motions (pt. I, ll. 231–232). By contrast, the adaptation discussed in *Ptolomeus* was computed for the Christian era and Julian calendar, with years beginning on 1 March (pt. I, ll. 241–256).

According to the detailed account in pt. II, the tables for each planetary mean motion consisted of six sub-sets representing minutes (30 entries from 2 to 60), hours (1 to 24), days (1 to 30), months (March to February), expanded years (1 to 20), and collected years (beginning with 1029 completed years). Each of these sub-sets displayed mean longitudes according to signs, degrees, minutes, and seconds of arc. The entries in the table for collected years were spaced by 20-year intervals and always referred to noon on the date in question, rather than the preceding noon.[19] The table for expanded years reckoned the 2nd, 6th, 10th, 14th and 18th year out of 20 years as bissextile (i.e., 366 days in length), in line with the fact that the first year in the collected-year table ran from 1 March 1030 to 28 February 1031. According to the collected-year table for the Sun, the mean longitude on 1 March 1030 (noon) was 344;30,20° (pt. II, ll. 423–427). In the corresponding sub-tables for days and hours, the respective first entries were 0;59,8° (l. 128) and 0;2,28° (ll. 123–124).

The expanded-year table for the Sun showed an increment of 0;9° after 20 years, which was also the difference between successive entries in the collected-year table (pt. I, ll. 250–256). It follows that these tables were based on a tropical year of 365d 5;49…h or approximately 365 ¼ – 1/131 days.[20] *Ptolomeus* mentions both forms of this value and treats it as a discovery attributable to al-Ṣūfī (pt. I, ll. 219–250; pt. II, l. 90). We know from the testimony of Ibn Yunus (d. 1007) that al-Ṣūfī proposed a solar motion of 359;45,40,2° per 365d.[21] The difference between the implied tropical year (365;14,32,29…d) and a Julian year

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[19] To take the beginning from the preceding noon was the more common approach in Islamic sets of astronomical tables such as the Toledan Tables. See on this point the commentary on *Lc*1 in part II.

[20] On the influence of this parameter in Latin Europe, see Nothaft 2017b: 221–222.

[21] See Mercier 1991: 1.

(365;15d) amounts to one day in 130;51,34,26… years. Mean-motion tables constructed on the basis of this precise value would show an increase of 0;9,2,18…° in 20 years rather than the round 0;9° added in *Ptolomeus*'s tables. This discrepancy seems innocuous, however, as it probably reflects no more than the use of rounded values in adapting al-Ṣūfī's tables to the format of the Julian calendar. Indeed, the tabulated excess of 0;9° results if al-Ṣūfī's solar motion per 365d is rounded down from 359;45,40,2° to 359;45,40°, multiplied by 20, and then increased by 5 × 0;59,8°/d for the five bissextile days contained in 20 years (20 × 359;45,40° + 5 × 0;59,8° = 7200;9°).[22]

Other than informing us in some detail about the parameters for the mean Sun, *Ptolomeus* mentions the following rates of planetary mean motion:

- Saturn: 0;2°/d (pt. III, ll. 308, 352, 383)
- Jupiter: 0;4,59°/d (l. 689)
- Mars: 0;31,26°/d (l. 704)
- Mercury (anomaly): 3;6,24° (l. 721)

Tables that mirror these parameters as well as the other specifications given in *Ptolomeus* have been preserved in the following Latin manuscripts:[23]

K	København, Det Kongelige Bibliotek, GkS 277 2°, fols. 183^{v} (Sun), 184^{r-v} (Moon and lunar anomaly), 185^{v} (lunar nodes and Saturn), 186^{v} (Jupiter), 187^{v} (Mars), 188^{v} (Venus), 189^{v} (Mercury) (s. XIII^{med})
L	Leiden, Universiteitsbibliotheek, Gronovius 21, fol. 54^{v} (Sun) (s. XII/XIII)
M	Madrid, Biblioteca Nacional de España, 10009, fol. 1^{r} (Saturn) (XIII$^{2/2}$)
O$_2$	Oxford, Bodleian Library, Selden supra 90, fols. 30^{r}–34^{r} (s. XII^{ex})
P	Paris, Bibliothèque nationale de France, lat. 16208, fol. 4^{r-v} (s. XII^{ex})
Q	Paris, Bibliothèque nationale de France, lat. 16207, fols. 19^{r} (Sun), 20^{v} (Sun repeated), 22^{r-v} (Moon and lunar anomaly), 24^{v} (Saturn), 28^{r} (Jupiter), 30^{r} (Mars), 32^{r} (Venus), 34^{r} (Mercury), 34^{v} (lunar nodes) (s. XIII)
V	Città del Vaticano, Biblioteca Apostolica Vaticana, Vat. lat. 3119, fols. 1^{v}–2^{r} (Sun), 7^{r}–8^{r} (Moon and lunar anomaly), 13^{r}–14^{v} (Moon and lunar anomaly, different recension); 21^{v}–22^{r} (Saturn), 25^{v}–26^{r} (Jupiter), 29^{v}–30^{r} (Mars), 34^{v}–35^{r} (Venus), 37^{v}–38^{r} (Mercury), 41^{v}–42^{r} (lunar nodes) (s. XII/XIII)

In *V*, the first entry in the collected-year table is for 1029 completed years, in perfect agreement with what is stated in *Ptolomeus*. This original starting point is also acknowledged in a note at the bottom of fol. 4^{r} in *P*, which is an inserted leaf. The mean-motion tables copied onto this leaf nevertheless move the initial epoch forward to 1169 years (= 1 March 1170), as do those in *K*, *L*, O_2, and *Q*. In all these copies, the entry for 1169 collected years is 345;33,20°, which is consistent with *Ptolomeus*'s stated *radix* of 344;30,20° for 1029 collected years and an increase of 0;9° × 7 = 1;3° in 140 years. The tables in O_2 lack a column for seconds of arc and the entries for minutes are rounded. It is also worth noting that the planetary mean motions per minute are here displayed in steps of 4 rather than 2. The collected-year tables in this manuscript originally only featured three lines for 1169, 1189, and 1209 years, but a later hand extended most of the tables down to 1309 years. Pedersen has persuasively argued that 1209 was the cut-off point in the archetype and that the additional entries found in the extant copies (continuing to 1249 in *K* and *L*; to 1289 in *P*; to 1309 in *Q* and *V*) were the work of later scribes.[24]

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[22] In my view, this makes unnecessary the worries expressed in Mercier 1991: 4–5.

[23] For previous discussions of these tables, known as the Tables of Pisa, see Mercier 1987: 110–112; 1991; Pedersen (Fritz) 2002: iii. 1208–1209 (CE20); 2007; Nothaft 2018a: 279–281, 297–298; Chabás 2019: 117–118, 122; Samsó 2020: 821–827.

Only *K*, *Q*, and *V* place the mean-motion tables in the company of any equation tables. In the case of *Q* (fols. 21^{r-v}, 23^{r}–24^{r}, 25^{r}–26^{v}, 28^{v}–29^{v}, 30^{v}–31^{v}, 32^{v}–33^{v}, 35^{r}–36^{r}), these tables do not differ substantially from those normally included in the Toledan Tables, which in turn go back to the famous *Ṣābiʾ Zīj* of al-Battānī (*c.* 900).[25] By contrast, the equation tables in *K* (fols. 183^{v}–190^{v}) and *V* (fols. 2^{r-v}, 4^{r-v}, 8^{v}–12^{v}, 16^{r}–20^{r}, 22^{v}–25^{r}, 26^{v}–29^{r}, 30^{v}–33^{r}, 34^{v}–37^{r}, 38^{v}–41^{r}) appear to stem from a separate source, as their entries frequently deviate from the 'Toledan' norm. A third set of equation tables that exhibits some significant similarities with those in *K* and *V*, but without sharing all their numerical variants, appears in a thirteenth-century Italian manuscript, here embedded in the context of the Toledan Tables:

N Napoli, Biblioteca nazionale 'Vittorio Emanuele III', VIII.C.49, fol. 22^{r}–42^{v}.

The divergence of these three witnesses from the 'vulgate' tradition of the Toledan Tables is especially noticeable in the case of the solar equation, whose maximum value they display as 1;59,8° rather than 1;59,10°. Another non-standard feature is their inclusion of a third column devoted to the solar declination (*remotio solis*), which relies on an unusual value for the obliquity of the ecliptic: 23;33,8°.[26] This obliquity value is elsewhere attributed to Azarquiel, its probable originator, as well as to Abraham Ibn Ezra.[27] Information about the solar equation table the author of *Ptolomeus* had before him can be extracted from a passage in pt. ii.iii, which explains how to find the mean longitude of the Sun from the time of the vernal equinox. The examples provided here indicate that the author's own table listed an equation of 1;58,47° for an argument of 273° (ll. 159–160) and 1;59,5° for an argument of 271° (ll. 168–170). Revealingly, this information is in perfect agreement with the columns in the non-standard solar equation table preserved in *K*, *N*, and *V*.

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[24] See Pedersen (Fritz) 2007: 15. The variants in the one-page fragment in *L*, which was not known to Pedersen, confirm this hypothesis.

[25] For an edition of these tables, see Pedersen (Fritz) 2002: iv. 1245–1307 (EA).

[26] In *V*, the column for the *remotio* appears in the solar equation tables on fols. 10^{r}–12^{v}, but not in the earlier rendition on fols. 2^{r-v}, 4^{r-v}. The same declination column is otherwise attested in the solar equation tables of MSS Edinburgh, Royal Observatory, Crawford Collection, Cr. 2.5, fols. 24^{v}–27^{r} (s. XIII^{med}); Paris, Bibliothèque nationale de France, lat. 7411,

Besides citing entries in the table for the solar equation, *Ptolomeus* also gives us maximum equations for the three superior planets (pt. iii, ll. 665–670), which are summarized in Table 1. These are mostly the same standard values as those used by the Toledan Tables and al-Battānī; yet, whereas these sources give Mars's maximum equation of anomaly as 41;9°, in line with Ptolemy's *Almagest*, our text uses the alternative value of 41;10° known from the *Handy Tables*.[28] The same is true of the equation tables in *K* (fol. 188^{v}) and *V* (fol. 32^{v}), which lends further support to the hypothesis that these tables go back to the set discussed in *Ptolomeus*.[29] It is not so in *N*, where the equation table for Mars (fol. 36^{r}) shows the conventional (Toledan) sequence of values for the entries near the maximum equation of anomaly. The existence of a deeper link between this manuscript's set of equation tables (*N*, fols. 22^{r}–42^{v}) and those presupposed in *Ptolomeus* is nevertheless evinced by some of the vocabulary used in the column headings, in particular the consistent use of *directio* for 'equation'. Headings that closely match the accounts of the lunar and planetary equations given in pts. iii.ii and iii.iii include *directio partis* for the lunar equation of anomaly, [*directio*] *circuli parvi* for the lunar increment as well as for the planetary equations of anomaly, and *directio puncti* for the planetary equations of centre. All columns for planetary minutes of proportion carry the instructions *minuit* or *crescit*, as expressly mentioned in our text (pt. iii, ll. 499–502, 654–658; see p. 171). It is striking, moreover, that the equation tables in *N* carry no columns for the first station, which resonates with the way *Ptolomeus* appears to assume that this information is provided in a separate table (see pp. 173–175).

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pt. B, fols. 24^{r}–25^{r} (s. $\mathrm{xiii}^{\mathrm{ex}}$), where the adjacent column for the solar equation conforms to the standard 'Toledan' values. See Pedersen (Fritz) 2002: iii. 967 (BA22).

[27] See Goldstein 1974: 96; Nothaft in Sela, Steel, Nothaft, Juste, and Burnett 2020: 216; Samsó 2020: 507, 629, 740.

[28] See the tabular summary of historical values in Chabás and Goldstein 2012: 77.

[29] This was overlooked by Pedersen (Fritz) 2007: 4, who writes that the equation tables in *K* show special values "[o]nly in the case of the Sun."

TABLE 1 Maximum equations of the superior planets according to *Ptolomeus*, III.iv

	Equation of centre	**Equation of anomaly**
Saturn	6;31°	6;13°
Jupiter	5;15°	11;3°
Mars	11;24°	41;10°

The canons in *K* (fol. 192$^{\mathrm{va}}$) and the related fragment in *G* claim that the mean-motion tables were originally composed "according to the climate of Pisa" (*composite secundum clima Pisanum*), which was presumably meant to indicate the meridian of reference. It is therefore likely to be more than an accident that some of the Toledan mean-motion tables (for Mars, Venus, and Mercury) in *N* (fols. 18$^{\mathrm{r}}$, 19$^{\mathrm{r}}$, 20$^{\mathrm{r}}$) are wrongly designated as valid for the meridian of Pisa, even though they appear in their standard form constructed on the basis of the Islamic lunar calendar and Hijri era.

The hypothesis of a link between the tables described in *Ptolomeus* and the meridian of Pisa receives full confirmation from the LRT, a text whose opening words present it as containing the teachings of "Abraham the Jew" (*Dixit Abraham Iudeus*).[30] The most plausible account of its origin is that the LRT, which dates itself to 1154, was the outcome of a collaboration between Abraham Ibn Ezra and a Christian scribe, to whom he dictated the text.[31] This *modus operandi* is clearly attested for Ibn Ezra's Latin treatise on the astrolabe, where one passage begins as follows:

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[30] Edition in Millás Vallicrosa 1947: 73–167. The text is preserved in the following MSS: Erfurt, Universitätsbibliothek, Dep. Erf. CA 4° 381, fols. 1$^{\mathrm{r}}$–28$^{\mathrm{r}}$ (s. XII$^{2/2}$; entitled *Liber Albumazar de astronomia*); Kraków, Biblioteka Jagiellońska, 573, pp. 224–253 (incomplete; s. XV); London, British Library, Cotton Vespasian A.II, fols. 27$^{\mathrm{ra}}$–31$^{\mathrm{vb}}$ (acephalous; s. XII/XIII); Madrid, Biblioteca Nacional de España, 10053, fols. 67$^{\mathrm{ra}}$–76$^{\mathrm{ra}}$ (s. XIII$^{2/2}$); Oxford, Bodleian Library, Digby 40, fols. 52$^{\mathrm{r}}$–88$^{\mathrm{v}}$ (s. XII/XIII); Paris, Bibliothèque nationale de France, lat. 7374A, fols. 102$^{\mathrm{r}}$–115$^{\mathrm{r}}$ (s. XIII); Paris, Bibliothèque nationale de France, lat. 16648, fols. 106$^{\mathrm{r}}$–146$^{\mathrm{v}}$ (s. XIII; entitled *Liber qui dicitur Abrahismus*); Paris, Bibliothèque nationale de France, lat. 16659, fols. 72$^{\mathrm{r}}$–101$^{\mathrm{r}}$ (incomplete; s. XIII$^{1/2}$). A brief excerpt (corresponding to LRT, p. 145, l. 4–p. 147, l. 16) appears in *C*, fols. 48$^{\mathrm{v}}$–49$^{\mathrm{r}}$.

[31] By contrast, Goldstein (1996: 15) considers it more likely that the LRT was translated directly from a Hebrew source text. On the evidence confirming Ibn Ezra's authorship of the LRT, see Millás Vallicrosa 1947: 13–17; 1949; Birkenmajer 1950; Sela 1996; 1997; 2003: 23–27. Note, however, that Sela (2020: 11–12) recently changed his position to asserting that the LRT could not have been composed by Ibn Ezra.

> Ut ait philosophorum sibi contemporaneorum Abraham magister noster egregius quo dictante et hanc dispositionem astrolabii conscripsimus …
>
> As our Master Abraham, outstanding among the philosophers of his time, at whose dictation we wrote also this account on the astrolabe says …[32]

The LRT's chief purpose was to elucidate a set of astronomical tables that included mean-motion tables for Pisa, which the text situates at 33° east of the western prime meridian (LRT, p. 87, ll. 20–21).[33] Ibn Ezra presents these tables as his own creation (p. 83, ll. 20–21; p. 84, l. 25; p. 87, ll. 2–3; p. 89, l. 17), expressly mentioning that he based them on the work of al-Ṣūfī (p. 87, l. 3). He also records his decision to arrange their collected-year tables for 20-year intervals in the Julian calendar, with a beginning of the year on 1 March, and that he put the bissextile intercalation in the 2nd, 6th, 10th, 14th, and 18th year of each expanded-year table (p. 87, ll. 7–19; p. 96, ll. 21–22). This placement of the bissextile years was a consequence of Ibn Ezra's choice of initial *radix*, which depended on a solar observation allegedly made by Azarquiel in year 482 of the Hijra (= AD 1089/90), when 1089 years of the Christian era were completed (p. 87, ll. 3–5). He designates the year of this observation as the *radix* both for the years that follow and for the years that precede it (p. 87, ll. 5–7: *et hec est radix annorum tam preteritorum ante hanc noticiam quam annorum hanc notitiam sequentium*), which suggests that his collected-year table contained earlier entries than for 1089 completed years. His statements are hence consistent with the tables described in *Ptolomeus*, which began with 1029 completed years.

The LRT also converges with *Ptolomeus* in revealing that the first entries in the Sun's sub-tables for minutes, hours, and days are 0;0,2°, 0;2,28°, and 0;59,8° (p. 95, ll. 27, 30–32; p. 96, ll. 4–11) and that the final entry in the table of expanded years is 0;9,0°, indicating a longitudinal increase of 0;9° in 20 years (p. 96, ll. 26–28; p. 97, ll. 1–3).[34] As was already mentioned, this increase implies a tropical year of approximately 365 1/4 – 1/131 days or 365d 5;49h, which is the year length *Ptolomeus* attributes to al-Ṣūfī. Ibn Ezra's familiarity with this year length as well as its association with al-Ṣūfī is clearly documented in his extant Hebrew writings. In the *Sefer ha-ʿOlam*, whose first version dates from 1148, he designates 365 ¼ – 131 days as the "correct value for our era," adding that al-Ṣūfī's determination of the Sun's longitudes was later confirmed by Azarquiel.[35] In the second version of his *Sefer ha-Ṭeʿamim* (*c.* 1154), he refers to a table for the excess of revolution that uses a tropical year of 365d 5;49h and an annual rotational excess of 87;15°.[36] According to the *Sefer ha-Moladot*, the correctness of this parameter had been "checked and demonstrated empirically for the past 200 years without an error of even one minute,"[37] Ibn Ezra's preferred parameter for the Sun's motion was hence identical with that employed in *Ptolomeus* and the corresponding tables. It is also worth noting that the LRT suggests that tables for the solar equation standardly include a column for the solar declination (p. 92, ll. 14–15), which is not generally the case in Latin equation tables, but does apply to those in *K*, *N*, and *V*.

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[32] See the edition in Millá Vallicrosa 1940: 28 and the translation of this passage in Smithuis 2006: 40, which I here reproduce. On this astrolabe treatise, see also n. 53 below.

[33] See on this value Samsó 2012: 188. According to Sela (1996: 209–212; 2003: 26), the reference to Pisa in a work written in 1154, when Ibn Ezra was in France, implies that there was a previous version of the LRT written in Pisa. Sela and Freudenthal (2006: 19, 31) date this previous version to 1142–1145. The argument is not wholly convincing, however, as it elides the difference between a set of tables and a treatise explaining the principles behind these tables, which can in principle be written at a separate occasion.

[34] Millás's edition has *2* instead of *9 minuta*, which must be emended on the basis of the Oxford manuscript. This was already noticed by Mercier 1991: 14.

In light of all this evidence, it is rather surprising that the LRT at one point seems to claim that the solar year in the Tables of Pisa lasts 365 ¼ – 1/136 days and that this is in accordance with a "demonstration" (*secundum probationem*) allegedly made by al-Ṣūfī, Ibn Sina, and Azarquiel (p. 95, ll. 12–15).[38] In another passage (p. 83, ll. 9–15), we are told that al-Ṣūfī, the Banu Sakir, Ibn Yunus, and Azarquiel all took the tropical year to have a rotational excess of 90° – 2;39° = 87;21°, which is equivalent to 5;49,24h. A solar year of 365d 5;49,24h would indeed be roughly the same as 365 ¼ – 1/136 days, although other passages in the LRT give the year length underlying the tables as 365d 5;49,22h (p. 95, ll. 20–24) or 365d 5;49,38h (p. 96, ll. 31–32). I have no hypothesis to offer that would fully explain these inconsistencies. It seems worth noting, however, that a thirteenth-century astronomical manuscript now in Paris preserves a canon in which it is claimed that "Abraham the Jew […] narrated the controversy among the philosophers" and affirmed a solar year of 365 ¼ – 1/126 days.[39] A table for the excess of revolution constructed on the basis of this approximate value (with a year length of 365d 5;48,12,30h and a rotational excess of 87;9,7,30°) appears later in the same codex.[40] It seems likely that this material is rooted in a misreading of the 365 ¼ – 1/136 days mentioned in the LRT, which devotes considerable space to contrasting the opinions of different past astronomers (the "controversy among the philosophers" mentioned in the Parisian canon).

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[35] *Sefer ha-ʿOlam* I, § 17:9–12 (ed. and trans. Sela 2010: 62–63). See also *Sefer ha-Ṭeʿamim* I, § 2.12:5 (ed. and trans. Sela 2007: 50–51); *Sefer ha-Ṭeʿamim* II, § 8.2:6, 10 (ed. Sela 2007: 250–251). Further references are provided in Sela 2014: 346, 393.

[36] *Sefer ha-Ṭeʿamim* II, § 6.3 (ed. Sela 2007: 238–239). See also *Sefer ha-Moladot*, IV.1:9, 4:2, 7:4 (ed. and trans. Sela 2014: 184–185, 188–189); *Sefer ha-Meʾorot*, § 35:5 (ed. and trans. Sela 2011: 482–483); *Sefer ha-Tequfah*, § 1:3, 2:2, 3:2 (ed. and trans. Sela 2014: 372–375).

[37] *Sefer ha-Moladot*, IV.1:9 (ed. and trans. Sela 2014: 184–185).

[38] As was already recognized by Toomer (1969: 318), the year length of 365 ¼ – 1/106 days given in Millás's edition (LRT, p. 95, ll. 13–14) must be emended to 365 ¼ – 1/136 days, as confirmed by MS Oxford, Bodleian Library, Digby 40, fol. 61^r.

Another apparent inconsistency that seems worth addressing concerns the meridian of reference of Ibn Ezra's mean-motion tables. While manuscripts *G* and *K* agree with the LRT in nominating Pisa, *V* creates a diverging lead. The tables are here preceded by one page of text (fol. 1ʳ), which is acephalous and must have originally been preceded by at least one other leaf. It opens with a canon on the subject of adjusting mean-motion tables to different geographic longitudes, in which it is assumed that the tables under discussion use the meridian of Lucca.[41] This reference to Lucca is reminiscent of a text discovered by Charles Burnett in MS London, British Library, Harley 5402, fol. 69ᵛ (s. XII$^{2/2}$).[42] It begins with the proclamation "Know that these tables were made for the city of Lucca" (*Sciatis quod tabule iste facte sunt super civitas Luce*) and goes on to indicate the meridian of Lucca as lying 34° east of the western prime meridian. The remainder of this note, which mixes Latin with an Italian *volgare*, is a simple instruction on how to adjust the mean-motion radices to other meridians. This is then followed by rules for calculating the true positions of the Sun and Moon from mean-motion and equation tables. As with the tables discussed so far, the year is here assumed to begin from March. Some of the technical vocabulary in these rules seems worth noting: the solar and lunar anomalies are both called *pars*, exactly as in *Ptolomeus*. The word for equation is *adob*(*b*)*ament*, such that the true anomaly becomes *pars adobata*. The double elongation is the *longitudo doppio*, while centre of the Moon is the *punto* (*punctus* in *Ptolomeus*).

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[39] MS Paris, Bibliothèque nationale de France, lat. 7411, pt. A, fol. 18ᵛ (s. XIII^{ex}): "Cum volueris scire quando intraverit Sol in puncto vernalis equinoctii secundum quod diffinivit Habraham Iudeus, qui narravit controversiam philosophorum et affirmavit annum solarem esse ex 365 diebus et quarta minus 126ª parte unius diei, et secundum hanc proportionem est composita tabula sua ad hoc constituta."

[40] MS Paris, Bibliothèque nationale de France, lat. 7411, pt. B, fol. 49ʳ.

[41] MS Città vel Vaticano, Biblioteca Apostolica Vaticana, Vat. lat. 3119, fol. 1ʳ: "Si autem ad alterius longitudinis civitatem medium cursum planetarum invenire desideras, longitudo inter eandem civitatem et Lucanam quot horarum sit considera. Tunc medium cursum planete in tot horis invenias. Quod si civitas illa fuerit a Luca in occidente, erit addendus medio cursui planete ad Lucanam inventa. Si vero fuerit in oriente, ab eodem est subtrahendus. Quod tunc remaneat erit medius cursus planete in hora quesita illius civitatis." This is followed by a passage locating Piacenza 20° east of Toledo.

[42] See the transcription in Burnett 2000a: 78–79. The previous page in the manuscript (fol. 69ʳ) contains a rule for computing the age and position of the Moon that mentions the year 1160, but there is no sign that it is directly related to the notes on fol. 69ᵛ.

The only astronomer of the twelfth or thirteenth century who is known to have cast astronomical tables for the city of Lucca is Abraham Ibn Ezra. According to Joseph ben Eliezer Bonfils (fourteenth century), to whose testimony we owe this information, his tables gave the longitude of Lucca as 34° from the western prime meridian, exactly as mentioned in MS Harley 5402.[43] From what is known about his itinerary, Ibn Ezra was active in Lucca and the Tuscan region between *c.* 1141 and 1145.[44] Bonfils also refers to a book on astronomical tables (or containing such tables) that Ibn Ezra wrote when he was in Narbonne,[45] where he is first attested in 1148. Ibn Ezra's preserved Hebrew works contain numerous references to one or more books on the subject of astronomical tables, so Bonfils's testimony seems dependable.[46]

Ptolomeus's claim that the tables under discussion were composed in 1143 would date them approximately to the middle of Abraham Ibn Ezra's Tuscan period. Two possibilities ought to be considered here. One is that these Tables of Lucca and the known Tables of Pisa are simply one and the same. The two cities are close enough in longitude that a set of tables cast for one place could have been used in the other without further adjustment. This may explain why *V* mentions Lucca despite its mean-motion tables exhibiting the same radices as the manuscripts that identify the meridian as that of Pisa. The other, arguably less parsimonious, possibility is that the Tables of Lucca are no longer extant and that the Tables of Pisa represent an adjustment to a neighbouring meridian.[47] What may seem to favour this hypothesis is that Joseph Bonfils's testimony has Ibn Ezra locate Lucca 34° from the west, whereas Ibn Ezra's LRT gives the longitude of Pisa as 33°. It may therefore be the case that Ibn Ezra re-cast his Tables of Lucca as Tables of Pisa upon visiting or moving to the latter city. That he had been to Pisa at some point before 1161 is suggested by the second version of his *Sefer ha-ʿOlam*, where Ibn Ezra testifies to having "verified by experience" the zodiacal signs ruling over both Pisa and Lucca.[48]

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[43] See the passage quoted in Sela 1996: 206.

[44] Millás Vallicrosa 1947: 17.

[45] See the passage quoted in Sela 1996: 206.

[46] The relevant documentation is provided in Sela 1996: 190–200.

[47] Sela (2020: 12) recently characterized the Tables of Pisa as "an adaptation of Ibn Ezra's Hebrew astronomical tables, now lost." He acknowledges "two possibilities: either Ibn Ezra was invited by Christian scholars to share with them the methods he used for his own astronomical tables composed during his stay in Lucca, or Christian scholars adapted their own astronomical tables from a Latin translation of Ibn Ezra's Hebrew astronomical tables." Sela's discussion makes no mention of the surviving Latin copies of the actual Pisan tables. He also provides no reason why the Tables of Pisa must be one step removed from Ibn Ezra himself.

Given Ibn Ezra's extensive travels, it is not much of a stretch to imagine that he re-computed his tables several more times as he changed location in Western Europe. A version for the meridian of Winchester is indeed attested in a passage attached to a partial Latin translation of a third version of the *Sefer ha-ʿOlam*.[49] While these tables have unfortunately been lost, some Latin manuscripts preserve mean-motion tables for the meridian of London that are structurally the same as the Tables of Pisa.[50] That these different versions had their roots in an adaptation of a *zīj* originally composed by al-Ṣūfī is itself a remarkable fact. Ibn Ezra is the only European astronomer of his time to show any awareness of al-Ṣūfī's length of the tropical year or of a *zīj* attributed to him. Rather than learning about al-Ṣūfī in his native Spain, it seems that Ibn Ezra's encountered the *zīj* in question only during his Italian sojourn. A hint in this direction is the characteristic presence of the Eastern forms of Hindu-Arabic numerals in several of the Latin manuscripts connected with Ibn Ezra and his Pisan Tables. As Charles Burnett has persuasively argued, these numerals may be taken as evidence that he had access to material that had recently been brought to Italy from the Levant, more specifically to the Republic of Pisa from the Principality of Antioch.[51]

A further source that can shed some light on the Tables of Pisa and their spread in Latin Europe is the *Tractatus magistri Habrahe de tabulis planetarum*, which appears under this rubric in *L*, fols. 56^{va}–63^{ra} (s. XII/XIII).[52] It contains rules for a set of Pisan tables very much like the ones described in *Ptolomeus* and the LRT. Their apogeal longitudes for the Sun and five planets were valid for 1149 completed years (fols. 56^{vb}, 57va), which may indicate that the initial *radices* of the corresponding mean-motion tables had been updated to 1 March 1150. The *Tractatus* otherwise contains very little information on the numerical content of these tables, although we are again told, as in the LRT, that Pisa is located 33° from the western prime meridian (fol. 56va). On fol. 60ra, the text cross-references a discussion of the astrolabe, which follows in the same manuscript on fols. 63ra–68^{vb} and is the very astrolabe treatise known to have been dictated by Abraham Ibn Ezra.[53] While the astrolabe treatise has also been transmitted separately, the London MS presents it and the *Tractatus magistri Habrahe* as two parts of a cohesive work.

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[48] *Sefer ha-ʿOlam* II, § 15:24–25 (ed. and trans. Sela 2010: 166–167); cf. also *Liber nativitatum* I.i.2:7 (ed. and trans. Sela 2019: 82–83); pseudo-John of Seville (= Abraham Ibn Ezra?), *Tractatus pluviarum*, § 55 (ed. Burnett 2008: 246–247); al-Kindī (?), *Liber de iudiciis revolutionum annorum mundi, tractatus primus*, § 6.3 (ed. in Sela, Steel, Nothaft, Juste, and Burnett 2020: 259). See Sela 1996: 210–212; 2003: 26; 2010: 207–208; 2019: 168.

[49] See my analysis in Sela, Steel, Nothaft, Juste, and Burnett 2020: 209–222.

[50] On these tables, see Mercier 1987: 108–109; 1991; North 2002: 15–19; Pedersen (Fritz) 2002: iii. 1209 (CE25); Chabás 2019: 118–120, and § 4 in part II of this volume.

[51] See on this point Burnett 1999: 165; 2000a: 13–15; 2002a: 251; 2003: 36–42; Smithuis 2004: 171–173; 2006: 52–54; Samsó 2012: 194–195; 2020: 824; Grupe 2019: 21.

[52] See Millás Vallicrosa 1947: 59–65; Mercier 1987: 111; 1991: 16–17; Burnett 1999: 164–165; Smithuis 2006: 30–33, 38–39.

Other than addressing the computation of mean motions, equations, and stations/retrogradations, the *Tractatus* contains rules for the solar declination (fol. 58^{r}) and for lunar and planetary latitudes (fols. 58^{rb}–59ra). To these it adds extended sections on the use of trigonometrical and ascension tables (fols. 60va–63ra), which goes to suggest that the Tables of Pisa were at one time a comprehensive *zīj*. The same impression arises from reading the LRT, where certain passages seem to presuppose that the reader has access to trigonometrical tables (p. 141, l. 7), solar declination tables (p. 143, l. 17), and ascension tables (p. 153, l. 17; p. 154, l. 2; p. 156, ll. 14–16; p. 157, l. 16). Another important witness to the presumed fuller scope of the Tables of Pisa is MS Berlin, Staatsbibliothek, lat. fol. 307, fol. 27^{ra-vb} (Northern France/Paris, s. XII$^{2/2}$), which features the *Tractatus magistri Habrahe* in a condensed two-page version headed *Liber de equationibus planetarum secundum meridiem Pissanorum*.[54] The text is here followed by several pages of astronomical tables (fol. 28^{r-v}, 30^{r}–32^{r}; the original order of these leaves is 30, 28, 31–32), none of which correspond to the familiar tables for mean motions and equations. Instead, the subjects covered include the lunar parallax, eclipse digits, planetary latitudes, right and oblique ascensions, and the time-equivalent of the mean motion in anomaly (for Mars, Venus, and Mercury). There are also some tables for the excess of revolution (fols. 28^{r}, 31^{v}), which happen to be based on a tropical year of 365d 5;49h. If this year length is one compelling indicator that the tables assembled on these pages are indeed related to the Tables of Pisa,[55] another other lies in the fact that Eastern forms of Indian numerals are employed throughout.

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[53] The astrolabe treatise was edited from this and another manuscript by Millás Vallicrosa 1940. For discussion, see Millás Vallicrosa 1944; del Valle 1989; Sela 2003: 31–36; Sela and Freudenthal 2006: 40–42; Smithuis 2004: 202–203, 212; 2006: 46–47; Rodríguez Arribas 2014: 249–258; Samsó 2012: 189–191; 2020: 414–417.

[54] See Burnett 2002a: 251, 256, 266; 2003: 36–37.

The existing hints that the mean-motion tables for Pisa were originally embedded in a comprehensive set contrast with the comparatively narrow range of functions acknowledged in *Ptolomeus*. Its almost exclusive focus on planetary longitudes (with motions in latitude being addressed only very briefly in III.vi) may reflect a conscious choice, perhaps guided by the intention to create an elementary text aimed at an audience with limited mathematical and astronomical experience. However, one should not discount the possibility that the text as transmitted in *C* is incomplete and that the original work contained further sections that addressed other operations and table-types, similar to what we find in the LRT and the *Tractatus magistri Habrahe*.

3 Authorship

Even beyond the link created by the Tables of Pisa, a systematic comparison between *Ptolomeus* and the more voluminous LRT reveals an overwhelming number of striking parallels, which are going to be documented in more detail in the commentary below. One particularly revealing trait shared between these two texts is their idiosyncratic presentation of Ptolemy's second lunar model, which transfers the lunar motion in anomaly from the epicycle to the deferent (see pp. 161–165). Another example are their respective references to Azarquiel's treatise *On the Solar Year* (*Ptolomeus*, pt. I, ll. 154–155; LRT p. 79, l. 21), which has not come down to us in any language. This lost work appears to be at the basis of the information, again reported in both texts, that Azarquiel believed the anomalistic year to have a different length from the tropical and sidereal years (*Ptolomeus*, pt. I, ll. 128–130; LRT, p. 79, l. 21–p. 80, l. 10). It is here worth recalling that the LRT (1154) was written nearly a decade after *Ptolomeus* (1145), yet frequently provides fuller information on the areas and topics covered in both texts. It therefore seems doubtful that any of these close correspondences can be explained as cases of one author borrowing from another. Instead, the two texts give the appearance of being two independent compositions that draw on a common pool of ideas, parameters, and doctrines. A straightforward way of accounting for this state of affairs would be to suppose that *Ptolomeus* and the LRT share the same author, namely, Abraham Ibn Ezra.

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[55] As already noted above (n. 36), tables for the excess of revolution on the basis of a year length of 365d 5;49h are expressly acknowledged in Ibn Ezra's *Sefer ha-Ṭeʿamim*. In fact, a second Latin copy of these tables for the excess of revolution appears together with a canon ("Cum volueris operari per tabulam revolutionum annorum …") in MS Erfurt, Universitätsbibliothek, Dep. Erf. CA 4° 379, fol. 102^{v} (s. XIV$^{1/2}$). Its values are here ascribed to both John of Seville and Abraham ("Tabula revolutionum annorum probata a peritis. Et est secundum Iyspalensem et Abraham, quamquam alii quidam alias composuerunt").

The same conclusion is urged by a comparison of *Ptolomeus* with Ibn Ezra's known Hebrew writings, which reveals at least two specific parallels that are independent of the aforementioned similarities with the LRT. One concerns *Ptolomeus*'s mention of a method that uses the Sun's noon altitude and knowledge of local latitude to determine the time of an equinox. The author remarks that this method has been "handed down elsewhere" (pt. II, ll. 141–142: *secundum artem alibi traditam*) and accordingly refrains from going into further detail. While no other Latin text known from the twelfth century discusses the method in question, we do find it described in the first version of Ibn Ezra's *Sefer ha-ʿOlam* (1148).[56] The other connection consists in *Ptolomeus's* allusions to there being 'left' and 'right' signs of the zodiac (pt. I, l. 150; pt. III, l. 834). This resonates with the way Ibn Ezra uses the Hebrew words שמאל ("left") and ימין ("right") in the second version of his *Sefer ha-Ṭeʿamim* (*c.* 1154), teaching that each zodiacal triplicity has a 'middle', 'left', and 'right' sign.[57]

A more general consideration that may be worth mentioning concerns the frequent references in *Ptolomeus* to Claudius Ptolemy, who is the chief authority for parts I and III.ii. His name appears 42 times over the course of the preserved text, sometimes in ways that appear to reflect first-hand familiarity with the content of Ptolemy's *Almagest*. In one instance, the author attributes to Ptolemy a specific statement, according to which it is "a great thing" (*magnum est*) to be able to determine mean longitudes to the nearest minute (pt. II, ll. 122–123).[58] Such special devotion towards Ptolemy and the frequent recourse to his astronomical insights is a well-attested hallmark of Ibn Ezra's writings, even including his biblical commentaries.[59] In his Hebrew translation of Ibn al-Muthannā's commentary on the tables of al-Khwārizmī, Ibn Ezra acknowledges the flaws of Ptolemy's astronomical tables, but in the same breath defends him by suggesting that his errors (such as assuming a tropically fixed solar apogee) stemmed from observational errors committed by his predecessors.[60] According to *Ptolomeus*, this was an interpretation shared by the Islamic astronomers who came after Ptolemy, and who continued to rely on his observations (pt. 1, ll. 193–203).

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[56] See *Sefer ha-ʿOlam* I, § 14:1–15:8 (ed. and trans. Sela 2010: 60–61), and the commentary on pt. II.iii.

[57] *Sefer ha-Ṭeʿamim* II, § 2.2:3–6 (ed. and trans. Sela 2007: 186–189).

[58] I have not been able to locate the source for this statement.

[59] See Sela 2003: 239–323.

On the basis of these considerations and the evidence presented here and in the previous section (see § 2), I am inclined to consider Abraham Ibn Ezra the author of *Ptolomeus*. As with Ibn Ezra's Latin astrolabe treatise, the LRT, and the astrological *Liber de nativitatibus*, this hypothesis does not require us to assume that Ibn Ezra himself wrote the text in Latin or even that he spoke the language proficiently. Rather, he can be imagined as having collaborated with a Christian scribe, who rendered into Latin a dictate received in some shared vernacular.[61] This style of collaboration, which was not unique in a twelfth-century context,[62] is also apt to explain some of *Ptolomeus*'s idiosyncratic vocabulary (see § 1 above). Its use of rare or unusual technical expressions (such as *iunctura circulorum* and *pars*) may reflect attempts on the part of the collaborator to find Latin equivalents for the terms Ibn Ezra used in his source language. Indeed, the expression *iunctura circulorum* has a clear parallel in the Hebrew מחברת שני הגלגלים ("intersection of the two circles"), as used in the *Sefer ha-Ṭeʿamim*.[63] Furthermore, the differences in vocabulary between *Ptolomeus* and the LRT, together with the decade-long gap that separates these two texts, would give us a reason to suppose that Ibn Ezra worked with different collaborators over time.[64]

The hypothesis of a text composed via dictate also opens a way towards neutralizing the main objection that has so far been raised against Ibn Ezra's authorship in the literature. It concerns the occasional use of the phrase *dominus*

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[60] Ibn al-Muthannā, *Commentary on the Astronomical Tables of al-Khwārizmī*, trans. Abraham Ibn Ezra (trans. Goldstein 1967: 149–150; excerpted in Sela 2003: 366–367).

[61] See on this point the illuminating discussion of Ibn Ezra's Latin works in Smithuis 2006 as well as the remarks in del Valle 1989; Burnett 1997: 58.

[62] On the method of 'translation from dictation', see Burnett 1985: 165–168; 2013: 356–358; Alverny 1989.

[63] *Sefer ha-Ṭeʿamim* 1, § 2.12:3, 6 (ed. Sela 2007: 50).

[64] The same goes for the substantially different spelling of proper names documented by Mercier 1991: 15. I shall here leave aside any discussion of how *Ptolomeus* may relate to Ibn Ezra's lost Hebrew writings on the subject of astronomical tables. Sela (2003: 22) postulates two versions of a *Sefer Ṭaʿamei ha-Luḥot* (or *Book of the Reasons behind Astronomical Tables*), one written in Lucca in 1146, the other in Narbonne between 1148 and 1154. Sela and Freudenthal (2006: 19–20, 31, 36, 38) even record three different versions, written in 1142–1145 (Lucca), 1148–1153 (Narbonne), and 1154 (Rouen), though the evidence for this seems open to debate.

noster Ihesus Christus when referring to the Christian era or its epoch date, which according to Mercier and Sela is indicative of a Christian rather than Jewish author (see p. 4). In evaluating this problem, it is important to note that the vast majority of references to years in the Julian calendar comes in the neutral form of "years of the Christians" (*anni Christianorum*), which could have easily been used by Ibn Ezra himself. Rather than being a pervasive feature of the text that characterizes the voice of the author, the two occurrences of "our Lord Jesus Christ" (pt. I, l. 217; pt. II, ll. 233–234: *domini nostri Ihesu Christi*) and the one reference to "the Lord's birth" (pt. II, l. 245: *in nativitate domini*) could easily have been inserted into the text by Ibn Ezra's scribe or collaborator. The view that these references necessarily indicate a Christian author for the treatise as a whole is therefore far from compelling.

4 Reception

Ptolomeus left a demonstrable imprint on two other twelfth-century texts, both of which are transmitted anonymously. The earlier of these is an unpublished text of approximately 1,500 words beginning *Inter omnes recte philosophantes*. It is known from a single copy in MS Parma, Biblioteca Palatina, 718–720, fols. 422v–423v, which was written in England in the early thirteenth century.[65] The text itself is even earlier, as seen from a passage that references the present year 1169.[66] Its content is to a large extent parallel to pts. I and II.i in *Ptolomeus*, dealing with the signs of the zodiac, the length of the tropical year, and precession. That it was directly dependent on *Ptolomeus* for information on these matters is evident from a long continuous passage that rephrases pt. I.v. This may be seen from the comparison below, which juxtaposes the beginning and end of this passage (right column) with the corresponding text in *Ptolomeus* (left column). Wording from *Ptolomeus* that recurs verbatim in *Inter omnes philosophantes* has been italicized.

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[65] For a description of the manuscript, see David Juste, "MS Parma, Biblioteca Palatina, 718–720" (update: 23.02.2017), *Ptolemaeus Arabus et Latinus. Manuscripts*, URL = http://ptolemaeus.badw.de/ms/146.

[66] MS Parma, Biblioteca Palatina, 718–720, fol. 423v: "[P]resenti tempore, id est anno domini 1169o, ingreditur primum minutum Arietis signi tertia [*sic*] die mensis eiusdem, ymaginem vero 23o die."

Ptolomeus, pt. I, ll. 157–163	Parma, Biblioteca Palatina, 718–720, fols. 422^{v}–423^{r}
Constat per longa intervalla temporum planetarum cursus et multiplices eorum varietates fuisse deprehensas a sapientibus in talium investigatione studiosissimis, nec unius hominis ad id deprehendendum perfecte suffecisse etatem. Potius partem a prioribus inventam et huic initio studio sequentium partem superadditam et nimirum efficiente rei difficultate diversas super huiusmodi perlatas sententias pro ingeniorum capacitate et studendi assiduitate.	Certum est autem *planetarum* motus et motuum *multiplicies varietates per longa temporum intervalla fuisse deprehensa⟨s⟩, nec unius hominis etatem* quantumlibet longam *ad* hoc *deprehendendum sufecisse*. Sed *part*i post *a prioribus invent*e *studio* sapientium *partem* aliam accessisse et hinc aliam et pro *ingeniorum capacitate* audendique *assiduitate* super hac inventione *diversas* diversorum *sententias* enituisse.
Ptolomeus, pt. I, ll. 164–175	
Predecessores Ptolomei, utpote Symon et Assimon investigatione horum diligentissimi scripto et memorie et posterorum scientie commendarunt quantum temporibus suis deprehendere potuerunt. Qui annum solarem per iuncturam mensi dixerunt anni revolutionem fieri in diebus 365 et VI horis et parte diei septuagesima sexta, ex qua parte singulis annis supputata in 76 secundum integram quartam annis dicebant diem accrescere. Unde anni ⟨secundum⟩ reditum Solis ad iuncturam post tot annos dicebant initium secundum diem in anteriora progredi, ut si in principio annorum 76 inciperet annus prima die Martii, post 76 completos a secundo die Martii esset initium anni. Et similiter de Luna et planetis investigaverunt secundum diversa spatia cursuum.	Puta *Simon et Asmon investigatione* talium *diligentissimi quantum temporibus suis deprehendere potuerunt script*um *poster*is reliquerunt, metientes *annum solarem 365 diebus et 6 horis et parte diei 76, ex qua singulis annis supputata in 76 annis diem* unum ex*crescere* assererunt, ut si aliqua die Martis Sol ingrederetur primum Arietis minutum *post completionem 76 annorum* 2^{o} *die* mensis eiusdem ingrederetur minutum idem. *Et similiter de Luna et planetis* aliis *investigaverunt*. […]
Ptolomeus, pt. I, ll. 214–218	
Fecerunt autem isti tabulas distinguentes cursus mediatos commensuratione temporis facta inter inventionis Ptolomei et inventionis sue tempore et secundum annos Alexandri ponentes radicem 1191 ab Alexandro. Sunt autem inter	*Fecerunt* etiam isti *tabulas* medios cursus planetarum *distinguentes secundum annos Alexandri, ponentes radicem 1151* [*sic*] *Alexandri super urbem Racham. Sunt autem inter an-*

annos Alexandri et annos domini nostri Ihesu Christi 311 anni. Incipit autem annus Albateni a mense Octobri et tabulas ⟨facte sunt⟩ super urbem Racham.

nos Alexandri, qui incipiunt ab Octobre, *et annos domini nostri Ihesu Christi 31* [*sic*] *anni* et 3 menses tres [*sic*].

Ptolomeus, pt. I, ll. 219–232

Hos secutus Assophius invenit tempore suo sine omni defectu quo die cuius mensis et quoti anni Sol intravit iuncturam. Quo relato ad inventionem Albateni comperit ab annis secundum hore sexte integritatem computatis 131 minuendum esse unum diem. Et cum ipsi invenissent Solem intrare iuncturam 16 die Martii, comperit intrare post annos 131 secundum iuncturam 15 die Martii. Unde facta commensuratione temporis inter eorum tempora probavit singulis annis in quarta diei, id est VI horis, supra 365 dies et 5 horas deesse partem diei 131 et a 90 gradibus deficere 2 gradus et 45 minuta. Et in tempore suo invenit infra 44 annos, in quibus singulis reditum Solis in gradibus, minutis et secundis diligentissimis inquisiverit experimentis, deesse 8 horas, scilicet tertiam diei, scilicet quod Sol per 8 horas tardius intravit iuncturam emensis 44 annis quam in eorum initio. Iste vero secundum inventionem suam fecit tabulas veracissimas habentes radices ab annis Machometi.

Hos sequtus Asophius, celestium motuum vir sapientissimus, *invenit tempore suo sine omni defectu quo die cuius mensis Sol intrar*et Arietem. *Quo relato ad inventionem Albateni* probavit *ab annis secundum integritatem sexte hore computatis 131 diem* integrum inveniendum esse, ut *cum ipsi invenissent Solem intrare* Arietem *16*^{to} *die Martis, comperit* eum *intrare post annos 131* eiusdem mensis *die 15*, asserens annum Solis constare ex *365 diebus et 5 hor*is et ad completionem sexte hore deficere *partem diei 131 et de 90 gradibus* qui ascendunt in 6 horis *deficere duos gradus et 45 minuta* fere. *Iste* quoque *secundum suam* inventionem tabulas veracissimas composuit ponens *radicem ab annis Mahometi.*

Ptolomeus, pt. I, ll. 233–242

Cuius inventionem Ezarchel secutus et ipsi innitens in tempore suo idem est diligentissime executus et inventionem suam nihilominus experimentum faciens experimentatus est inventionem Assophii nullum prorsus habere defectum et similiter post emensionem annorum 131 invenit diem minuendum esse. Et expertus est Solem intrare in iuncturam post 131 annos secundum iuncturam sumptos 14 die Martii cum illius predicti tempore intrasset 15 die Martii. Qui etiam tabulas veracissimas composuit. Et

Azacel autem in tempore suo *experimentum faciens expertus est inventionem Asophii nullam prorsus admittere* fallaciam *et post emensionem 131 annorum esse* inveniendum unum *diem*, ut cum tempore illius Sol intraret Arietem *15 die Marti*s, *post 131 annos 14 die* eiusdem mensis ingrederetur. Iste etiam sue inventionis *tabulas composuit veracissimas* que tabulis Asophii firma-

inde recipiendas quod tabulis et inventioni Assophii et dant et accipiunt inde fidem. Unde tabule Assophii posterorum experimentis ⟨non⟩ invente sunt dampnabiles.

mentum *dant et fidem* ab eis *accipiunt.*

A curious claim contained in this passage in *Inter omnes philosophantes* is that Hipparchus was active 560 years after Meton and Euctemon.[67] While this interval does not appear directly in *Ptolomeus*, it could have been inferred from two corrupt numbers in *C* (pt. I, ll. 176–177): 800 (for 600) years between Meton/Euctemon and Ptolemy and 240 (for 280) years between Hipparchus and Ptolemy (800 – 240 = 560). It is nevertheless clear that the author of *Inter omnes philosophantes* had access to a better source than *C*, as he simultaneously transmits the correct interval between Hipparchus and Ptolemy (280 years) and once cites the correct interval of 743 years between Ptolemy and Thābit/al-Battānī, for which *C* (pt. I, ll. 210, 212) always substitutes 643.[68] It is interesting to note that the text that precedes *Inter omnes philosophantes* in the same manuscript is a twelfth-century introduction to planetary theory, the *Liber de motibus planetarum* (fols. 418^{v}–422^{r}), excerpts of which follow in *C* immediately after *Ptolomeus* (see the Appendix below). In the Parma manuscript, and only here, the text comes with a marginal note identifying it as *De motibus planetarum secundum Abraham* (fol. 418^{v}).

The other twelfth-century work that borrows demonstrably from *Ptolomeus* is an anonymous compilation on practical geometry with extended astronomical sections, which is extant in more than a dozen manuscripts and known by its incipit as *Artis cuiuslibet consummatio*.[69] From internal evidence, it appears that its author wrote in Paris in the year 1193. That he had access to *Ptolomeus* can be seen from a chapter on the solar year, which effectively paraphrases segments of pt. I.i–iii. The chapter's dependency on *Ptolomeus* is particularly clear from the opening lines, which are here compared with the source text:

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[67] MS Parma, Biblioteca Palatina, 718–720, fols. 422^{v}: "Post hos fuit Abrachaz 560 annis fere, qui scriptis eorum diligenter innitens qua die cuius mensis Sol ingrederetur Arietem suo tempore determinavit, dicens annum ex 365 ⟨diebus⟩ et 5 horis et sexta incompleta constare. Quantitatem vero defectus non determinavit."

[68] MS Parma, Biblioteca Palatina, 718–720, fols. 422^{v}: "Diffinito tamen tempore inter ipsum et Abrachaz, scilicet 280 annis, Thebras et Albarenus [*sic*], qui post Ptolomeum 643 [*sic*] annis studio sapientie enituerunt, determinato qua die cuius mensis planetarum quilibet Arietem intraret, invenerunt 7 dies minuendos in 743 annis, ut si sol tempore Ptolomei die Martis 23^{a} intrasset Arietem, post emissionem tot annorum 16^{a} die eiusdem mensis ingrederetur."

[69] Edition and English translation in Victor 1979: 108–471.

Ptolomeus I.i (ll. 12–15)	*Artis cuiuslibet consummatio* 2.27 (ed. Victor 1979: 286)
Indi autem metiuntur annum solarem secundum stellas fixas, dicentes annum Solis esse reditum de stella fixa ad eandem, utpote a stella fixa in initio signi Arietis ad eandem, vel a loco alto ad locum altum. Et dicunt annum habere 365 dies et 6 horas et partem diei centesimam vicesimam.	*Indi autem annum sol*is computant *secundum reditum* eius a *stella fixa ad eamdem*. Et continet *365 dies et 6 horas et centesimam et 20*^{am} *partem diei.*[70]

Aside from this instance of near-verbatim borrowing, it is also worth noting that *Artis cuiuslibet consummatio* gives the value of the obliquity of the ecliptic as 23;33,8° and the maximum solar equation as 1;59,8°.[71] As mentioned previously (see § 2), these non-standard values characterize a table for the solar equation that accompanies the Tables of Pisa in *K* and *V* (with a separate attestation in *N*) and was evidently also known to the author of *Ptolomeus*. The suggested link between *Artis cuiuslibet consummatio* and the Tables of Pisa is strengthened further by its chapter on planetary apogees, which cites a set of apogeal longitudes for the present year 1193. Not only are these longitudes broadly the same as those listed in one copy of the tables (O_2), but the text is explicit in stating that the apogees move at an annual rate of 0;0,51°/d.[72] As will be argued below (pp. 140–142), this parameter was at the basis of a table for precession that probably belonged to the Tables of Pisa in their original form.

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[70] The text continues as follows (see Victor 1979: 286–288): "Ptholomeus autem a iunctura ad iuncture reditum metitur annum et continet 365 dies et 6 horas, 30 [*sic*] parte unius diei minus. Latini vero ponunt integras 6 horas tantum cum 365 diebus in anno solis grossam facientes computationem. Cum ergo secundum Ptholomeum sol intravit arietem i.e. iuncturam, i.e. lineam equinoctialem in 23 die martii, sed secundum Yndos in 13 die, sed hodierno die fit econtrario, intrat enim arietem 13 die martii secundum Ptholomeum, que est 23 die secundum Yndos. Et est idem dies, 13^{us} dies martii secundum Ptholomeum qui est 23^{us} secundum Yndos. Estque moderno tempore ipsa iunctura, scil. equinoctialis linea, scil. initium arietis in 22° gradu piscium secundum Yndos. Et ibi est equinoctium revera, similiter in 22° gradu virginis. Indi enim signa secundum ymagines computant."

[71] *Artis cuiuslibet consummatio* 2.10, 25 (ed. and trans. Victor 1979: 240–241, 278–281).

[72] *Artis cuiuslibet consummatio* 2.26 (ed. and trans. Victor 1979: 282–285).

5 Transmission

C = *Cambridge, Fitzwilliam Museum, McClean 165, fols.* 67^{r}–75^{v} (*s. xii/xiii* [*after 1175*])[73]

This copy of *Ptolomeus et multi sapientum* belongs to a parchment codex of 139 leaves (225–40 × 155 mm) containing two separate collections of texts, one dedicated to astronomy (fols. 1^{r}–88^{v}), the other to logic (fols. 89^{r}–139^{v}, consisting of three formerly independent units). Its precise origins are unknown, although some eclipse observations noted on fols. 66^{r} and 139^{r-v} indicate that the relevant parts of the codex were in the possession of Sint-Truiden Abbey (Limburg) by the year 1285.

Our text extends across two quires (fols. 67–73, 74–80), all in the same hand, but its end is nowhere marked by any definite break or colophon. Some cataloguers and commentators have judged the text to continue to the end of fol. 80^{v},[74] while others have claimed that it finishes on fol. 76^{v}.[75] Closer inspection reveals that a new text already begins with the penultimate line on fol. 75^{v}, continuing from there to fol. 76^{v}. Most of this segment is concerned with defining concepts in planetary theory, in particular the different terms involved in computing the equation. The technical vocabulary used in these definitions diverges strongly from that in the preceding sections of *Ptolomeus*, thus reinforcing the impression that they belong to a different text. That there is a rupture at this point was already recognized by Pedersen, who in his 1990 edition of *Investigantibus astronomiam primo sciendum* gave the page-range of *Ptolomeus* in *C* as folios 67^{r}–76^{v}, but added that "f. 75^{v}–76^{v} consist of definitions and may be a separate work."[76] In fact, most of the definitions appear more or less verbatim in an anonymous *Liber de motibus planetarum*, known from at least nine other manuscripts (see p. 26), which can roughly be dated to the third quarter of the twelfth century.[77]

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[73] Published descriptions: Narducci 1892: 185–187 (no. 320); James 1912: 316–319; Leonardi 1960: 23–24 (no. 31); Robinson 1988: i. 72 (no. 230); Burnett 1987: 180; 1990: 363; Pedersen (Fritz) 2002: i. 95–96; Alverny, Burnett, and Poulle 2009: 37–39; Morgan and Panayotova 2009: 12–13 (no. 144); Thomson 2013: 38–39; https://collection.beta.fitz.ms/id/object/170728.

[74] See, e.g., James 1912: 318; Lipton 1978: 190 (n. 24); Mercier 1991: 28.

[75] Mercier 1987: 110; Nothaft 2017b: 221 (n. 34); 2017c: 279 (n. 24), 290 (n. 56); 2018b: 154 (n. 21); 2018c: 98 (n. 77), 138 (n. 105).

[76] Pedersen (Fritz) 1990: 211.

[77] See the textual comparison in Nothaft 2018b: 156–157. In this earlier publication, I still considered these definitions in *C* to be part of *Ptolomeus* and therefore argued for the dependence of the *Liber de motibus tabularum* on the latter text, rather than vice versa.

A substantial portion of the material that follows after *Ptolomeus* until the end of the quire on fol. 80^{v} does not seem to be attested elsewhere. Readers interested in this material are referred to the description included below in the Appendix to this part of the volume. Fol. 80^{v} contains a reference to the year 1175, which has led some cataloguers to claim that *C* as a whole was copied before this year.[78] This cannot be the case, however, seeing as the preceding page (fol. 80^{r}) contains material excerpted from a *computus* treatise written in that very year.[79] By consequence, 1175 ought to be understood as a *terminus post quem*, at least for the two quires containing *Ptolomeus* (fols. 67–80).[80]

O = *Oxford, Bodleian Library, Selden supra 26, fols. 122^{r}–129^{v}, 101^{r}–105^{v} (s. xii/xiii)*[81]

This partial copy of the text belongs to a parchment codex of 133 leaves (180/90 × 113/37 mm), most of which is devoted to arithmetic. The book was brought to St Augustine's Abbey, Canterbury by William de Clara (1242/3–after 1283), but its ultimate origins remain unknown.[82] Fols. 96 to 129 have been bound of sequence. The original order is: fols. 106–121 (the *Liber Alchorismi de practice arismetice*), 96–100 (the 'Toledan *regule*', an arithmetical and algebraic text closely connected with the preceding *Liber Alchorismi*),[83] 122–129 (*Ptolomeus*), 101–105 (*Ptolomeus*). According to Barker-Benfield, the book originally included fols. 30–37 in the contemporary codex O_2.[84] This is not wholly implausible, seeing as fols. 30^{r}–34^{r} of this quire contain a copy of the mean-motion tables for Pisa (see § 2). It should be noted, however, that the use in this copy of the conventional Western forms of Hindu-Arabic numerals sets it apart from fols. 96–100 and 106–129 in *O*, where the comparatively rare Eastern forms are employed.

This does not, however, affect the suggested dating of the *Liber de motibus planetarum* to the third quarter of the twelfth century (ibid., 163).

[78] James 1912: 316; Leonardi 1960: 23–24. Robinson 1988: i. 72 (no. 230) suggests a date "c. 1175", noting that "this date suits the appearance of the writing."

[79] On this text, see Nothaft 2017a. The borrowings on fol. 80^{r} are documented in the Appendix below.

[80] The correct dating of "soon after 1175" was deduced by Morgan and Panayotova 2009: 13, who note that it "applies to fols. 1–88, not just to fols. 67–80."

[81] Published descriptions: Madan and Craster 1922: 624–625 (#3414); Karpinski and Waters 1928: 47; Burnett 2002a: 259; Burnett, Zhao, and Lampe 2007: 142–143; Barker-Benfield 2008: iii. 1805.

[82] Burnett (2002a: 254) has suggested the possibility that the scribe was Italian. On William de Clara's books in Canterbury, see Barker-Benfield 2008: iii. 1879–1882.

[83] See Burnett, Zhao, and Lampe 2007.

[84] Barker-Benfield 2008: iii. 1805.

Previous discussions of *O* in the literature have failed to point out that the copy of *Ptolomeus* on fols. 122–129 is continued on fols. 101–105.[85] The text on fols. 122–129 covers sections II.i to II.iv, l. 293. It skips the remainder of II.iv and continues with III.i to III.ii, reaching l. 272 at the end of fol. 129^v. The final words on fol. 129^v, *quanta fuerit differentia partis*, are repeated at the beginning of fols. 101–105, which continue the text to III.iii, breaking off in l. 622 (*Et ad evidentiam directionem quandam subtraximus*). This break occurs in the middle of the fifth line of fol. 105^v, leaving the rest of the page blank (a standard page of this quire has *c.* 30 lines). The copying ceased immediately before a worked example for the calculation of the true longitude of Saturn, which was also skipped over in *C*, except for a few words.

The repetition of words at the beginning of fol. 101^r appears to coincide with a change in scribal hands. It is in fact noticeable that the second part of *O*'s copy (i.e., fols. 101^r–105^v) contains a much higher frequency of scribal errors than the preceding one (i.e., fols. 122^r–129^v). The scribe of the first part mixes Roman numerals with Hindu-Arabic numerals in their Eastern forms.[86] Since these forms are a known feature of other manuscripts connected to Abraham Ibn Ezra and the Tables of Pisa,[87] their presence in *O* is likely to be a vestige of the archetype. In *C*, the Eastern forms only appear on fols. 48^v–49^r, which contain an excerpt from Ibn Ezra's LRT.[88] The scribe of the second part in *O* consistently stuck to Roman numerals, presumably converting any Hindu-Arabic numerals he found in his exemplar. Another feature frequently encountered in the first part of the copy in *O*, but avoided by the scribe of the second part, is the use of symbolic notation for the Sun, Moon, and zodiacal signs.

6 Editorial Principles

The following edition of *Ptolomeus* is based on the two known manuscript witnesses, *C* and *O* (see § 5). The critical apparatus records all significant variants between these two copies, including changes in word order. It ignores mere differences in spelling or minor slips of the quill (e.g., *altim* for *altum*). The use of *c/t* in words such as *inicium/initium* has been normalized throughout in favour of classical conventions. For instance, preference has been given to *initium* over *inicium*.

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[85] See Pedersen 1990: 212; Nothaft 2018b: 154 (n. 21), and the literature cited in n. 81.

[86] See the table in Burnett 2002a: 266, for a transcription of these forms.

[87] See Burnett 2002a: 249–251, 253–254, 266–267, 279–283.

[88] Burnett 2002a: 256.

Where the two manuscripts give equally plausible variants or merely put words in a different order, I have as a general policy opted for the readings in *O*. A peculiar and systematic divergence between them concerns the grammatical genus of sexagesimal minutes, seconds, and other fractions, which normally should take the neutral form (*minutum*, -a; *secundum*, *-a*; *tertium*, *-a* etc.). This is indeed the case in *O*, whereas *C* routinely substitutes female forms (*minuta*, *-ae*; *secunda, -ae*; *tertia*, *-ae*; *quarta*, *-ae*). In cases of this nature, I have always followed *O*'s usage while ignoring the variant in *C*.

O comes in two parts written by different hands (fols. 122^{r}–129^{v} and 101^{r}–105^{v}), of which the first is characterized by its parallel use of Roman numerals and Hindu-Arabic numerals in their Eastern forms (especially for larger numbers). In *C*, Hindu-Arabic numerals are used almost throughout, albeit in in their more common Western forms. In the interest of consistency, I have followed *C* in its choice of numeral forms, as this is the only manuscript to cover the entirety of the text presented here. Cases where *O* merely shows the same numeral in a different form have not been recorded in the apparatus. Where the manuscripts present Roman numerals with case endings (in superscript), I have normally substituted the complete word.

There are several instances where the preserved text appears to be affected by significant omissions. Such suspected gaps will be indicated by ⟨…⟩. The critical apparatus employs the following abbreviations:

a.c.	state of the text before correction
gem.	text doubled
om.	text omitted
om. per hom.	text omitted as a consequence of homeoarchy or homoioteleuton
add.	text added
s.l.	text added above the line

In translating *Ptolomeus* into English, I have tried to remain close to the wording and sentence structure of the Latin text. Nevertheless, there were instances where it seemed advisable to take certain liberties with grammar and syntax to ensure readability. In handling the text's technical astronomical terms, I have sometimes opted for modern equivalents rather than literal translations. This is the case with the terms *locus altus* and *augis*, which will be rendered as "apogee" throughout the text. Likewise, I have used "perigee" to translate a variety of expressions such as *locus imus*, *oppositum loci alti*, and *oppositum augis*.

The text frequently uses *iunctura* or *iunctura circulorum*, which literally means "the place where the circles join" or "are joined" to refer to the equinoctial points (or, typically, to the point of the vernal equinox). As explained in the opening sentence of *Ptolomeus* (1.i, l. 4), the circles that join at this place are those of "the firmament and [the sphere] above" (*firmamenti et superioris*), meaning the ecliptic and the celestial equator. My translation renders the expression *iunctura circulorum* literally at this first occasion, but otherwise substitutes "equinoctial point" for being simpler and technically accurate. In a similar vein, I have used "equator" as a technical term to translate *equinoctialis linea*. Yet another case of this nature is the text's use of *pars* to refer to a planet's anomaly. Apart from a few passages in III.ii, where context demanded a literal translation ("part"), I have opted for the modern term "anomaly" throughout.

Context permitting, the ecliptic longitudes mentioned in the Latin text have been converted into modern notation for the translation. Thus, *11 signa, 29 gradus, 59 minuta, 60 secunda* (as in II.iii, l. 155) may appear in the translation as 11s 29;59,60°.

Ptolomeus et multi sapientum …
Ptolemy and many among the sages …

∴

I ⟨De quantitate anni⟩

⟨I.i⟩

C 67$^{\mathrm{r}}$ Ptolomeus et multi sapientum annum solarem metiuntur secundum reditum Solis a iunctura circulorum, scilicet firmamenti et superioris, ad eandem iuncturam. Et spatium huius reditus dicunt esse 365 dies et 5 horas et 55 minuta et 12 secunda et deesse de quarta diei partem diei trecentesimam. Et hic annus dicitur ab eis ‘annus remotionis’, quia inde Sol incipit declinare a linea equinoctiali. Et hic annus astronomicorum est, qui rationes circulorum et cetera ad opus suum necessaria, utpote obscurationes luminarium, investigant, postponentes iudicia et non curantes de signis vel eorum nominibus.

Indi autem metiuntur annum solarem secundum stellas fixas, dicentes annum Solis esse reditum de stella fixa ad eandem, utpote a stella fixa in initio signi Arietis ad eandem, vel a loco alto ad locum altum. Et dicunt annum habere 365 dies et 6 horas et partem diei centesimam vicesimam. Et hic annus est astrologorum, qui iudicia attendunt et imagines componunt secundum signa, attendentes etiam eorum nomina et coniunctionem planetarum cum fixis stellis. In quo eis concordes inveniuntur Thebit Christianus et Abuchalich Ebetine et multi sapientes.

Unde, quia Sol citius redit ad circulorum iuncturam quam ad stellam fixam vel ad initium signi, evenit ut maior sit annus secundum Indos quam secundum Ptolomeum. Stelle enim firme moventur motu proprio et similiter et tantundem movetur locus altus, ut cum discesserit a loco alto suo, redit ad alium locum altum, sub alio scilicet gradu.

Invenitur enim Sol tempore Ptolomei fuisse in loco altiori in 4 gradibus Geminorum. Presenti tempore invenitur in loco altiori in 27 gradibus Geminorum cum minutis. Cor vero Leonis tempore Ptolomei in 3 gradu, presenti tempore in 18 gradu Leonis invenitur. Sic et alie stelle fixe moventur motu proprio, ut cum Sol recedat in loco aliquo a stella, cum redierit ad locum illum non invenit stellam illam et progreditur ut consequitur illam. Initium autem signi Arietis antiquitus fuisse in ipsa circulorum iunctura. Unde et ipsa iunctura antiquum nomen retinet capitis Arietis, cum tamen caput Arietis, id est ipsius signi, hoc tempore per 9 gradus ab ipsa iunctura inveniatur remotum. Et caput Leonis invenitur remotior a iunctura quam ab initio signi per 9 gradus, quia cum sit in 9 gradu Leonis distat a iunctura 129

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6 55] 50 *C* 17–18 planetarum] stellarum fixarum *C* 25 in^{2}] id est *C* 26 27] 18 *C* 28 18] 6 *C* 33 9] 5 *C* 34 caput] cor *C* 35 129] 139 *C*

1 On the Length of the Year

1.i

Ptolemy and many among the sages measure the solar year according to the Sun's return to the place where the circles—namely, of the firmament and [the sphere] above—join. And they say that the period of this return is 365 days, 5 hours, 55 minutes, and 12 seconds and that 1/300th of a day is missing from the quarter-day. And they call this [type of] year the 'year of departure' [*annus remotionis*] because it is from this point onwards that the Sun begins to bend away from the equator [*linea equinoctiali*]. And this is the year of the astronomers, who investigate the dispositions of the circles and the other things required for their work, such as the eclipses of the luminaries, while they set aside judgments and do not worry about the signs or their names.

The Indians, by contrast, measure the solar year according to the fixed stars, saying that the year is the Sun's return to a fixed star, namely, to the fixed star at the beginning of the sign of Aries, or [its return] to the apogee. And they say that the year has 365 days and 6 hours and 1/120th of a day. And this is the year of the astrologers, who apply themselves to judgments and construct talismans according to the signs, paying attention also to their names and the conjunction of the planets with the fixed stars. Thābit the Christian, *Abuchalich Ebetine*, and many sages are found to agree with them [sc. the Indians] on this [point].

Since the Sun returns sooner to the equinoctial point [*ad circulorum iuncturam*] than to a fixed star or to the beginning of a sign, it consequently happens that the year according to the Indians is longer than that according to Ptolemy. For the fixed stars move by their own motion and the apogee moves in the same way and by the same amount, so that once [the Sun] has departed from its apogee, it returns to a different apogee, that is, one that is below a different degree.

For it is found that the Sun in Ptolemy's time was at the apogee when at 4° Gemini. At the present time, it is found at the apogee when at 27° Gemini with [an addition of some] minutes. But the heart of the Lion is found to have been in the 3rd degree in Ptolemy's time, in the 18th degree of Leo at the present time. Likewise, the other fixed stars move in this way by their own motion, such that when the Sun departs from a star at some place, it does not find this star when it returns to this place and it [must] advance to catch up with it. The beginning of the sign of Aries was in former times [found] to have been at the equinoctial point [*in ipsa circulorum iunctura*]. On account of this, this point retains its ancient name of 'head of Aries', even as the head of Aries (i.e., of the sign) is now found at a distance of 9° from

gradus, ab initio vero signi Arietis per 120. Adeo presenti tempore remotum est signum a iunctura per temporis intervallum. Coniuncta fuissent, nunc autem in iunctura est 22 gradus Piscium. Et cum dicitur equinoctium esse cum Sol est in capite Arietis, de iunctura intelligendum est, et pocius Sol est in 22 Piscium, non in signo Arietis. Iunctura autem illa est in equinoctiali linea et ibidem super 22 gradus Piscium. Nec negant Indi in 22 Piscium equinoctium esse.

⟨1.ii⟩

Cum itaque in vocabulis est diversitas, in ipsius rei veritate nulla invenitur varietas. Est enim duplex partitio: secundum Ptolomeum una, secundum Indos altera. Ptolomeus enim ab equinoctiali linea et ab ipsa iunctura que est in ea incipit dividere signa per tricenos gradus, non curans de signis distinctis secundum vicinitatem imaginum, nec attendens si initium signi secundum imaginem inventi in eadem iunctura sit an non. Inventum est tamen prius per aliquod intervallum in eadem iunctura fuisse initium signi secundum imaginem. Sed quoniam, ut diximus, stelle fixe moventur, citius redit Sol ad equinoctialem lineam et ad iuncturam quam ad initium signi secundum imaginem.

Indi, non attendentes quando ad iuncturam redeat Sol secundum annum eorum, similiter firmamentum in 12 signa diviserunt. Et dederunt eis nomina a circumstantia vicinarum stellarum, quarum pars est infra iuncturam, pars extra. Cum enim quasdam figuras stellarum discernerent variis modis dispositarum, huic nomen Arietis, illi nomen Tauri, et similiter, indederunt. Cum igitur divisissent cincturam totam in 12 partes ex circumstantia stellarum in figuris ipsas, partes designaverunt earum nominibus, utpote primam partem duodecimam Arietem et signum Arietis vocaverunt, cum tamen ipsa figura non totum signum comprehendat. Incipit enim figura in 12 gradu signi et sunt eius stelle diffuse hinc illinc per longitudinem et latitudinem figure.

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36 120] 129 *C*   58 indederunt] indiderunt *C*

this point. And the head of Leo is 9° farther from the equinoctial point than from the beginning of the sign, for when it is at 9° Leo, it is 129° from the equinoctial point, but 120° from the beginning of the sign of Aries. This is the amount by which the sign has become removed from the equinoctial point at present through the passage of time. They were once joined together, but now the equinoctial point corresponds to the 22nd degree of Pisces. And when it is said that the equinox [*equinoctium*] occurs when the Sun is at the head of Aries, this must be understood as referring to the equinoctial point [*de iunctura*], and the Sun is then rather in the 22nd [degree] of Pisces, not in the sign of Aries. This equinoctial point is located on the equator and there above the 22nd degree of Pisces. Neither do the Indians deny that the equinox occurs at the 22nd [degree] of Pisces.

1.ii

And so, even though there is a difference in the words used, one finds no disagreement when it comes to the truth of the thing itself. For there are two methods of partition: one according to Ptolemy, the other according to the Indians. For Ptolemy begins to divide the signs into 30° from the equator and from the equinoctial point that lies on it, neither worrying about the signs as defined by the proximity of the constellations [*imaginum*], nor paying attention to whether or not the beginning of a constellation-based sign coincides with this equinoctial point or not. It is nevertheless true that at a certain time in the past the beginning of a constellation-based sign was at this particular point. Yet since the fixed stars move (as we have said), the Sun returns sooner to the equator and to the equinoctial point than to the beginning of a constellation-based sign.

The Indians, who according to their [type of] year do not pay attention to when the Sun returns to the equinoctial point, similarly divided the firmament into 12 signs. And they gave them names based on the mutual positions of neighbouring stars, some of which are on this side of the equinoctial point, others on that side. For upon discerning certain configurations of stars arranged in various ways, they introduced for this one the name ‘Aries’, for that one the name ‘Taurus’, and so on. Accordingly, once they had divided the whole girdle into 12 parts based on the mutual positions of the stars in these configurations, they marked these parts with their names, inasmuch as they called the first twelfth part ‘Aries’ and ‘the sign of Aries’, irrespective of the fact that the configuration itself does not encompass the whole sign. For the configuration begins in the 12th degree of the sign and its stars are spread out here and there across its longitude and latitude. There are also some where the configurations extend further in longitude and latitude

In quibusdam etiam porriguntur ipse figure plus quam signa in longitudine et latitudine. Sed ab ipsis figuris non sunt existentie vel distinctiones signorum. Itaque vocantur signa secundum distinctionem Ptolomei eiusdem nominibus quibus et signa secundum distinctionem Indorum. Et ubi est caput Arietis secundum Ptolomeum, ibi 22 gradus 〈Piscium〉 secundum Indos. Et ubi est 〈9〉 gradus Arietis secundum Ptolomeum, ibi est primus gradus Arietis secundum Indos.

Itaque secundum distinctionem Ptolomei et nomina omne opus astronomice est, ut diximus, exercendum. Quantum vero ad iudicia minuendi sunt 8 gradus, ut secundum nomina pars maior iuditiorum procedat 〈a〉 22 Piscium aut reliquorum et ab ascendente et casis et angulis et aspectibus *C* 67^{v} et ceteris iudicialibus minuantur 8 gradus. Ut si | etiam secundum tabulas experimenti Sol inveniatur in primo gradu, minuantur 8 gradus et dicatur in 22 Piscium et omnia iudicia sumenda tamquam 22 Piscium. Et cum secundum astrolabium inveniatur altitudo et inventus fuerit Sol in capite Arietis et supponatur retis pars in qua est caput Arietis super altitudinem inventam et secundum eam positionem hora inveniatur et alia astronomica, propter iudicia supponatur 22 gradus Piscium altitudo et inveniantur astrologica. Pars autem 〈minor〉 iudiciorum secundum nomen Arietis exercenda est.

〈I.iii〉

Ex his predictis nihilominus patet ratio secundum quam in diebus Ptolomei cum Sol intraret caput Arietis, scilicet iuncturam in lineam equinoctialem, in 23 diebus Martii, secundum Indos in 14 die Martii intrasse inveneretur. Nunc econverso secundum rationem Ptolomei inveniatur Sol intrare caput Arietis 14 die Martii, secundum Indos in 23 die Martii, quia Ptolomeus secundum iuncturam, Indi secundum stellam firmam annum faciunt. Et hinc videtur fieri decrementum, illinc incrementum, hac ratione. Annus Christianorum solaris facientium supputationem crassam et sine minutis constat ex 365 et quarta diei, scilicet VI horis, cum secundum Ptolomeum a sexta hora desit pars diei trecentesima et secundum Indos porrigatur ultra VI horas 120 diei pars. Secundum alios etiam 〈…〉. Et Christiani non sequuntur

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73–74 22 piscium] secundum secundum piscis *C* 76 experimenti] inveniatur *add. a.c. C* 77 piscium] piscis *C* 81 piscium] piscis *C* ‖ inveniantur] inveniatur *C* 85–86 equinoctialem] et *add. C* 94 120] *C*

than do the signs; yet the signs exist and are marked-off independently from the configurations themselves. The signs according to Ptolemy's definition are hence called by the same names as the signs according to the definition used by the Indians. And where the head of Aries is located according to Ptolemy, there is the 22nd degree of Pisces according to the Indians. And where the 9th degree of Aries is located according to Ptolemy, there is the first degree of Aries according to the Indians.

All astronomical operations must, as we have said, be carried out according to Ptolemy's definition and names. When it comes to [astrological] judgments, however, one must subtract 8 degrees, such that according to the names the greater part of judgments proceeds from the 22nd [degree] of Pisces or of the remaining [signs] and 8 degrees are subtracted from the ascendant, the houses, the cardines, and from the other things related to judgments, so that even when one finds according to observation-based tables [*tabulas experimenti*] that the Sun is in the first degree, one must subtract 8 degrees and say that it is in the 22nd of Pisces and all judgments must be taken as if it were in the 22nd of Pisces. And when the [solar] altitude is found with an astrolabe and the Sun has been found at the head of Aries and the part of the rete corresponding to the head of Aries is placed above the altitude found, and the hour and other astronomical things are found in accordance with this position, for the sake of judgments the 22nd degree of Pisces must be placed above the altitude and astrological [parameters] must be found [on this basis]. The smaller part of judgments, however, must be performed according to the name of Aries.

I.iii

From these foregoing statements it also becomes clear why it is the case that in the days of Ptolemy, while the Sun entered the head of Aries (meaning the equinoctial point located on the equator) on 23 March, it was found to have entered on 14 March according to the Indians. Conversely, it is now the case that the Sun is found to enter the head of Aries on 14 March according to Ptolemy's method [and] on 23 March according to the Indians, which is owing to the fact that Ptolemy defines the year according to the equinoctial point, the Indians according to a fixed star. And one can see from this that there is a decrease on one side, an increase on the other, which [happens] for the following reason. The solar year of the Christians, who make a rough calculation without minutes, consists of 365 [days] and a quarter-day (i.e., 6 hours), whereas according to Ptolemy the sixth hour lacks 1/300th of a day and according to the Indians [the year] stretches out further than 6 hours by 1/120th of a day. According to others it is also ⟨...⟩. And the Christians follow

rationem Ptolomei omnino secundum iuncturam annum facientes, nec rationem Indorum secundum stellam firmam, sed maiorem quam Ptoloemus, minorem quam Indi annum faciunt. Unde secundum Ptolomeum minuitur ab anno Christianorum pars trecentesima et secundum Indos additur pars 120.

Hinc itaque est quod secundum Ptolomeum, cum in anno Christianorum Sol intret Arietem presenti tempore 14 die Martii, post intervalla annorum intrabit 13, deinde 12 die Martii. Et cum secundum Indos intret Sol presenti tempore 23 Martii in anno Christianorum, post temporis cursum magnum intrabit 24, et deinceps. Item, cum Christiani faciunt integram sextam singulis annis, cum desit pars diei trecentesima, evenit in trecentis annis per collectionem temporis totum diem minuendo a compoto Christianorum, ut secundum Christianos, cum sint completi anni trecenti, desit unus dies propter partem singulis annis deficientem et tamen a Christianis supputatam. Et cum sint completi 300 anni secundum Ptolomeum, superaddendus sit dies ad complementum annorum 300 Christianorum. Propter quam defectionem, cum Sol intraverit Arietem primo anno trecentorum 14 die Martii, inde procedit decrementum. Eadem ratione pretermittunt incrementum secundum Indos, qui annum maiorem computant quam Christiani. Et terminatis annis 300 Christianorum nondum terminentur anni 300 secundum ipsos, sed superaddendum est ad complementum istorum sicut secundum Ptolomeum minuendum.

Ex predicta minutione sexte secundum Ptolomeum facienda invenientur a tempore Ptolomei ad tempus Thebith et Albateni 2 dies minuti ab numero secundum Christianos et intrasse in eorum tempore 2 diebus minutis a tempore Ptolomei, tamquam intrasset suo tempore 23 die Martii et in eorum in 14 [!]. Nec erit contrarietas inter Ptolomeum et Indos, cum iste alium annum, illi alium assignent. Potius concordia, si idem dies fuerit 14 secundum Ptolomeum et 23 secundum Indos, qui sicut initia signorum et diffinitiones, sic etiam menses diversificant supputando.

Sunt tamen et alii qui secundum iuncturam maius anni spatium putant, ut Symon et Assimon sextam horam integre ponentes et supra partem diei septuagesimam sextam et 76 annis diem addendum compoto Christianorum. Azarchel tertiam annorum varietem assignare volens dixit annum esse

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112 inde] unde *C* 118 numero] Christianorum *add. C* 126 sextam] VI *C* 128 Azarchel] Ezarchel *C*

neither Ptolemy's method by defining the year entirely in terms of the equinoctial point, nor the method of the Indians according to a fixed star, but make the year greater than Ptolemy, smaller than the Indians. According to Ptolemy 1/300th [of a day] is subtracted from the year of the Christians and according to the Indians 1/120th is added.

This, then, is the reason why if the Sun according to Ptolemy enters Aries at the present time on 14 March in the Christian calendar, after a period of years it will enter on 13, then on 12 March. And if the Sun according to the Indians enters [Aries] at the present time on 23 March in the Christian calendar, after a long period of time it will enter on the 24th, and so on. Likewise, since the Christians reckon the sixth [hour] as complete in each year, given that 1/300th of a day is actually missing, it happens that after 300 years a whole days that has been accumulated over time must be subtracted from the reckoning of the Christians, such that, when 300 years are completed according to the Christians, one must take away one day because of the part that is lacking yet reckoned by the Christians; and when 300 years are completed according to Ptolemy, one must add a day to complete 300 years of the Christians. As a result of this shortfall, when the Sun enters Aries in the first of 300 years on 14 March, a decrease will subsequently ensue. In the same way, [the Christians] leave out the increment according to the Indians, who calculate the year as longer than the Christians. And according to their [length], 300 years are not yet complete when 300 years of the Christians have been completed, but instead one must make an addition to complete these years, just as a subtraction must be made according to Ptolemy.

From the aforementioned subtraction from the sixth [hour] that must be made according to Ptolemy, one will find that between the time of Ptolemy and the time of Thābit and al-Battānī two days were subtracted from the number according to the Christians and that [the Sun's] entry [into Aries] in their time was two days earlier than in Ptolemy's time, as if it had entered on 23 March in his time and on the 14th [!] in theirs. And there will not be a contradiction between Ptolemy and the Indians, seeing as they assign different years. Rather, there will be agreement, provided the 14th according to Ptolemy is the same day as the 23rd according to the Indians, who here reckon differently with the months just as they do with the beginnings and boundaries of the signs.

Nevertheless, there are also others who consider the length of the year according to the equinoctial point to be greater, as do Meton and Euctemon, who take the sixth hour as complete with an addition of 1/76th of a day and [assume] that one day must be added to the reckoning of the Christians in 76 years. Azarquiel, wishing to postulate a third type of year, said that the year

cursum Solis de loco alto ad locum altum et locum altum magis moveri quam stellam fixam. Quod a veritate alienum est.

Sciendum autem et iuncturam predictam et initium signi et imaginis ‘caput Arietis’ vocari. Unde, ne error generetur, diligenter attendendum est quando de iunctura, quando de reliquis sermo fiat.

⟨i.iv⟩

Dixerunt Indi stellas firmas non moveri proprio motu. Tamen nunc elevatiores a terra, nunc propinquiores secundum firmamentum, quod dicebant permutare punctum suum aliquibus intervallis temporum, et partes eius quasdam propinquiores, quasdam remotiores, et in eandem nunc propinquiorem, nunc remotiorem. Et in capite Arietis et Libre, scilicet in duabus iuncturis, duos circulos esse dicunt per quos elevatur vel deprimitur caput Arietis et Libre et firmamentum et inde provenire inequales reditus Solis a iunctura ad iuncturam, ut interdum maiore, interdum minore temporis spatio Sol ad iuncturam redeat, et inequales provenire Solis annos secundum iuncturam attentos, sed secundum stellam fixam semper equales provenire annos.

Alii Indorum negant predictam elevationem et depressionem secundum circulos Arietis et Libre, sed eius motionem magis dextram interdum, aliquando magis sinistram dicunt et caput Arietis et Libre nunc magis sinistrum, nunc magis dextrum; et tunc elevatius esse cum est magis sinistrum, depressius cum magis dextrum, sicut videmus sinistra signa altiora et dextra depressiora. Et dicunt per 8 gradus fieri hanc motionem versus dextram et *C* 68ʳ versus sinistram | et inde dicunt provenire inequales reditus Solis ad caput Arietis, scilicet ad iuncturam, et annos secundum hoc inequales, sed secundum stellam firmam equales semper provenire annos. Azarchel, in libro DE ANNO SOLARI, hec omnia nititur explanare.

⟨i.v⟩

Constat per longa intervalla temporum planetarum cursus et multiplices eorum varietates fuisse deprehensas a sapientibus in talium investigatione studiosissimis nec unius hominis ad id deprehendendum perfecte suffecisse etatem, potius partem a prioribus inventam et huic initio studio sequentium partem superadditam et nimirum efficiente rei difficultate diversas super

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154 Azarchel] Ezarchel *C*

is the Sun's period of motion from apogee to apogee and that the apogee moves more than a fixed star. This is contrary to the truth.

One should know, however, that the aforementioned equinoctial point and the beginning of the sign and constellation are [all] called 'head of Aries'. To keep an error from arising, one must therefore pay careful attention to when reference is made to the equinoctial point [and] when to the others.

I.iv

The Indians said that the fixed stars do not move by their own motion but are nevertheless now farther from the Earth, now nearer, on account of the firmament, which they said changes its point over certain time intervals, and [that] some of its parts are nearer, others are more remote, and now nearer to [the Earth], now more remote from it. And they say that there are two circles at the heads of Aries and Libra, namely, at the two equinoctial points, by which the heads of Aries and Libra as well as the [whole] firmament are raised and lowered, and that this results in unequal returns of the Sun to the equinoctial point, such that the Sun returns to this point now in a longer time span, now in a shorter one, and that it results in unequal solar years as [defined] according to the equinoctial point, whereas [defining the year] according to a fixed star always results in equal years.

Others among the Indians deny the aforementioned raising and lowering according to the circles [at the heads] of Aries and Libra, but they instead say that its motion [sc. of the firmament] is sometimes more towards the right, sometimes more towards the left and that the heads of Aries and Libra are now more to the left, now more to the right. And [they say that] it is higher when more to the left, lower when more to the right, just as we consider left signs to be higher and the right ones to be lower. And they say that this motion to the right and to the left goes on for 8°. And they say that this results in unequal returns of the Sun to the head of Aries, that is, to the equinoctial point, and that the years thus defined are unequal, whereas [defining the year] according to a fixed always results in equal years. Azarquiel attempts to explain all of this in a book ON THE SOLAR YEAR.

I.v

It is well known that the motions of the planets and their manifold variations have been discovered over long time spans by sages who were highly devoted to the investigation of such things and that no one man's lifetime was enough to make all these discoveries. Rather, one part was found by an earlier generation and another part was added to this beginning through the efforts of those who came next. And it is surely as a result of the difficulty of

huiusmodi perlatas sententias pro ingeniorum capacitate et studendi assiduitate.

Videtur autem tali ratione hec processisse investigatio. Predecessores Ptolomei, utpote Symon et Assimon investigatione horum diligentissimi, scripto et memorie et posterorum scientie commendarunt quantum temporibus suis deprehendere potuerunt. Qui annum solarem per iuncturam mensi dixerunt anni revolutionem fieri in diebus 365 et VI horis et parte diei septuagesima sexta. Ex qua parte singulis annis supputata in 76 secundum integram quartam annis dicebant diem accrescere. Unde anni ⟨secundum⟩ reditum Solis ad iuncturam post tot annos dicebant initium secundum diem in posteriora progredi, ut si in principio annorum 76 inciperet annus prima die Martii, post 76 completos a secundo die Martii esset initium anni. Et similiter de Luna et planetis investigaverunt secundum diversa spatia cursuum. Et huius inventionis scripta reliquerunt. Fuerunt autem ante tempus Ptolomei annis fere 600.

Post hos fuit Abracaz ante tempus Ptolomei 280 annis, qui et sue inventionis scripta relinquens asserit annum quem mensus est secundum iuncturam, ut priores, habere dies 365 et 5 horas et sextam incompletam. Quo etiam die et cuius mensis Sol ad iuncturam reverteretur tempore suo designavit. Et sic de aliis planetis. Cuius scriptis Ptolomeus innitens invento qua die mensis Sol intret tempore suo caput Arietis, scilicet iuncturam, commensuratione temporis inter eorum inventiones collegit Solem redire ad iuncturam diebus 365 et 5 horis et ad complementum sexte deesse partem diei 300, omissis scriptis Symonis et Assimonis, quoniam in ipsis non invenit diei designatione, quo die scilicet tempore eorum Sol iuncturam intraret vel alii planete. Unde collegit Ptolomeus supputata singulorum annorum parte predicta diem esse minuendum a 300 annis secundum integram sextam mensuratis et post tot annos annum incipere a sequenti [!] die mensis illius a cuius precedenti [!] intraverat initio annorum 300, ut si primum intrasset 24 die mensis Martii, post tot annos emensos 23 die Martii intrare deberet iuncturam. Et similiter de aliis planetis investigavit.

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165 assimon] adsymon *C* 172 posteriora] anteriora *C* 176 600] 800 *C* 177 280] 240 *C* 179 sextam] 6 *C* 184 sexte] 6 *C* 185 assimonis] adsymonis *C*

this thing that different opinions have been announced on this subject, in accordance with [people's] intellectual ability and the degree of care with which they applied themselves to it.

It is understood, however, that this investigation proceeded in the following way. Ptolemy's predecessors, namely, Meton and Euctemon, who were highly careful in the investigation of these things, entrusted to the memory and knowledge of future generations the sum of what they could discover in their own time. Having measured the solar year according to the equinoctial point, they claimed that the year completes its revolution in 365 days, 6 hours, and 1/76th of a day. They said that from this part that is reckoned for each year a day accrues in 76 years that contain [only] a whole quarter-day. In accordance with this, they said that after this many years the beginning of the year [as defined] according to the Sun's return to the equinoctial point moves forward with respect to the date, such that if the first of 76 years began on 1 March, at the end of 76 years the beginning of the year would be on 2 March. And they made the same type of investigation for the Moon and the planets according to their different periods of motion. And they left writings about this finding. [The time when] they were active, however, was 600 years before Ptolemy's time.

After them [came] Hipparchus, who was active 280 years before Ptolemy's time. He also left behind writings [documenting] his finding, asserting that the year that he, like his predecessors, measured according to the equinoctial point has 365 days, 5 hours, and an incomplete sixth [hour]. He also indicated the day and month on which the Sun would return to the equinoctial point in his time and did the same for the other planets. Relying on his writings and having found on which day of which month the Sun enters the head of Aries (i.e., the equinoctial point) in his time, Ptolemy used the time between their findings to gather that the Sun returns to the equinoctial point in 365 days and 5 hours with 1/300th of a day being missing to complete the sixth [hour], while leaving aside the writings of Meton and Euctemon, because he did not find in them an indication of the date, that is, the day on which the Sun and the other planets entered the equinoctial point in their own time. Reckoning the aforementioned part for every single year, Ptolemy accordingly gathered that one day must be subtracted from 300 years that are measured according to six complete hours, and that after this many years the year begins on the day of the month that follows [!] the one on which it had entered [Aries] at the beginning of 300 years, such that if it had initially entered the equinoctial point on 24 March, it would be due to enter it on 23 March after the end of this many years. And he made the same sort of investigation for the other planets.

Quas inventiones Ptolomeus secutus temporis interiacentis commensuratione cursus mediatos planetarum distinxit et tabulas composuit. Que tamen inventio et distinctio et tabularum compositio a posteris est reprehensa, non quantum ad tempus suum falsa comperta, sed ob causam Abracaz, quem in sua inventione deceptum fuisse autumant. Cui inventioni Ptolomeus innitens, licet quo die cuius mensis tempore suo Sol iuncturam intraret recte deprehenderit, falsas nimirum reliquit tabulas de cursibus mediatis. Ipsum vero secutus est Ptolomeus, quia nullum in arte tali invenit fortiorem. Unde posteri reliquentes initia Abracaz, initia tamen Ptolomei non omiserunt. In scriptis etenim suis determinavit quo die et cuius mensis Sol et ceteri planete iuncturam tempore suo intrarent. Cui inventioni Thebith et Albatene innitentes, omissa sententia ipsius de reditu ad iuncturam, tempore suo deprehenderunt quibus diebus cuius mensis et quoti anni intrarent planete iuncturam. Cumque post ipsum fuissent annis 743 deprehenderunt quot dies in tot annis minuendos esse a compoto Christianorum secundum sextam integram. Et cum diebus Ptolomei invenisset Solem 23 die Martii intrare in annis Nabugodonosor, ipsi deprehenderunt Solem 16 die Martii post annos illos Nabugodonosor emensis 743 et inde deprehenderunt a quarta diei, scilicet VI horis, desse partem 106. Quoniam partitis in 7 diebus quos invenerunt minutos esse 743 ⟨…⟩. Ex quorum inventione videtur distinctio cursuum mediatorum secundum Ptolomeum facta redarguenda. Fecerunt autem isti tabulas distinguentes cursus mediatos commensuratione temporis facta inter inventionis Ptolomei et inventionis sue tempora et secundum annos Alexandri ponentes radicem 1191 ab Alexandro. Sunt autem inter annos Alexandri et annos domini nostri Ihesu Christi 311 anni. Incipit autem annus Albateni a mense Octobri. Et tabulas super urbem Racham.

Hos secutus Assophius invenit tempore suo sine omni defectu quo die cuius mensis et quoti anni Sol intravit iuncturam. Quo relato ad inventionem Albateni comperit ab annis secundum hore sexte integritatem computatis 131 minuendum esse unum diem. Et cum ipsi invenissent Solem intrare iuncturam 16 die Martii, comperit intrare post annos 131 secundum iuncturam 15 die Martii. Unde facta commensuratione temporis inter eorum tempora

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206 743] 643 *C* 208 sextam] VI *C* 210 743] 643 *C* 211 106] 104 *C* 212 743] 643 *C* 213 Ptolomeum] The(?) *C* 221 sexte] VI *C*

Basing himself on these findings, Ptolemy used the measurement of the intervening time to determine the mean motions of the planets and to construct tables. This finding, determination, and construction of tables was nevertheless rejected by those who came afterwards, not on account of any false measurements made in his own time, but because of Hipparchus, whom they judge to have made an error in his finding. Since Ptolemy relied on this finding, there can be no doubt that he left behind incorrect mean-motion tables, even though he correctly determined the day and month on which the Sun entered the equinoctial point in his time. But the reason Ptolemy followed [Hipparchus] is that he found no one who was greater in this art. Those who came afterwards accordingly did not omit Ptolemy's beginnings, even as they abandoned Hipparchus's beginnings. For he indicated in his writings the day and month on which the Sun and the other planets entered the equinoctial point in his time. Relying on his finding while having discarded his opinion about the return to the equinoctial point, Thābit and al-Battānī determined the day, month, and year on which the planets entered the equinoctial point in their own time. And since they were active 743 years after him, they determined the number of days that must be subtracted in this many years from the reckoning of the Christians according to the completed sixth [hour]. And whereas Ptolemy had found that the Sun entered [Aries] on 23 March of the year of Nabonassar in his time, they determined that the Sun [did so] on 16 March at the end of 743 of these years of Nabonassar and discovered from this that 1/106th [of a day] was missing from a quarter-day (i.e., from six hours). For if 743 are divided by the 7 days that they found to have been subtracted 〈…〉. From their finding one sees that Ptolemy's conclusion with regards to the mean motions must be repudiated. Now these men made tables by extracting the means motions from the measured time interval between Ptolemy's finding and the finding in their own time and by placing the root-date at the 1191st year of Alexander according to the era of Alexander. But the difference between the era of Alexander and the era of Our Lord Jesus Christ is 311 years. Al-Battānī's year, however, begins from the month of October. And the tables are for the city of ar-Raqqah.

Following in their wake, al-Ṣūfī found in his own time without any defect the day, month, and year on which the Sun entered the equinoctial point. Having compared this to al-Battānī's finding, he ascertained that one day must be subtracted from 131 years that are reckoned according to the completed sixth hour. And while [Thābit and al-Battānī] had found that the Sun entered the equinoctial point on 16 March, he ascertained that after 131 years [as defined] according to the equinoctial point it entered on 15 March. Based

C 68$^{\text{v}}$ probavit | singulis annis in quarta diei, id est VI horis supra 365 dies et 5 horas [!], deesse partem diei 131 et a 90 gradibus deficere 2 gradus et 45 minuta. Et in tempore suo invenit infra 44 annos, in quibus singulis reditum Solis in gradibus, minutis, secundis diligentissimis inquisiverit experimentis, deesse 8 horas, scilicet tertiam diei, scilicet quod Sol per 8 horas tardius intravit iuncturam emensis 44 annis quam in eorum initio. Iste vero secundum inventionem suam fecit tabulas veracissimas habentes radices ab annis Machometi.

Cuius inventionem Azarchel secutus et ipsi innitens in tempore suo idem est diligentissime executus et inventionem suam nihilominus faciens experimentatus est inventionem Assophii nullum prorsus habere defectum et similiter post emensionem annorum 131 invenit diem minuendum esse. Et expertus est Solem intrare in iuncturam post 131 annos secundum iuncturam sumptos 14 die Martii cum illius predicti tempore intrasset 15 die Martii. Qui etiam tabulas veracissimas composuit et inde recipiendas quod tabulis et inventioni Assophii et dant et accipiunt inde fidem.

Unde tabule Assophii posterorum experimentis ⟨non⟩ invente sunt dampnabiles, unde et secundum ipsius tabulas nostre sunt composite, in quibus facta est coequatio annorum Christianorum in quibus sexta hora integre computatur cum annis Assophii secundum iuncturam, ut cum minor sit annus secundum iuncturam emensi anni Christianorum 131 uno die minus sint completi 131 anni iuncture. Quoniam minores sunt anni iuncture 131 annis Christianorum totidem uno die, id est uno diurno circulo secundum 360 gradus. Unde evenit ut 20 anni iuncture 9 minutis graduum minores sint totidem annis Christianorum. Quod patebit si attenderis quota pars de minutione illius diei in 131 annis pertineat ad 20 annos. Inde etiam est quod in tabulis nostris in tabula annorum separatorum Solis invenies Solem adicere 20 annis 9 minuta ut habeamus cursum Solis mediatum secundum annos Christianorum. Quoniam in 20 annis iuncture nihil in signis vel gradibus vel minutis debent inveniri. Apposite igitur sunt ibi 9 minute ad habendum cursum Solis in 20 annis Christianorum, quibus 9 minutis vincuntur anni iuncture 20 a 20 annis Christianorum.

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228 secundis] *s.l. C*   233 Azarchel] Ezarchel *C*   234 nihilominus] experimentum *add. C*
248 360] 36 *C*   250 20] 2 *C*

on the measured interval between their [respective] times, he accordingly demonstrated that in every year the quarter-day (i.e., the 6 hours that are above 365 days and 5 hours [!]) is short by 1/131 of a day and that 2;45° are missing from 90°. And in his own time he found that 8 hours (i.e., one-third of a day) go missing within 44 years, in each of which he examined with extremely careful observations the Sun's return according to degrees, minutes, and seconds—meaning that Sun entered the equinoctial point 8 hours later at the end of 44 years than at their beginning. This man, however, used his findings to make highly accurate tables that used the era of Mohammed for their root-date.

Following in the wake of his finding and relying on it, Azarquiel accomplished the same with the highest care and, making his own finding, he determined by observation that al-Ṣūfī's finding has no defect whatsoever and he found like him that one day must be subtracted at the end of 131 years. And his observation showed him that after 131 years [as defined] according to the equinoctial point the Sun entered this point on 14 March whereas in [al-Ṣūfī's] time it had entered on 15 March. He also constructed tables that are highly accurate and worthy to be accepted, seeing as they both confirm the tables and the finding of al-Ṣūfī and derive confirmation from them.

The tables of al-Ṣūfī have not been disproved by the observations of those who came after him, which is also why his tables have been used as the basis for our own tables, in which the years of the Christians, in which the sixth hour is reckoned as complete, are measured against al-Ṣūfī's years according to the equinoctial point, inasmuch as 131 years of equinoctial point have one day less than 131 years of the Christians, owing to the fact that the year [as defined] according to the equinoctial point is shorter. For 131 years of the equinoctial point are one day shorter than as many years of the Christians, that is to say, by one diurnal revolution of 360°. This is why 20 years of the equinoctial point are 0;9° shorter than the same number of years of the Christians, which will become clear if you consider which part of the one day subtracted in 131 years pertains to 20 years. It is also the reason why in our tables, in the table for expanded years, you will find that the Sun adds 0;9° in 20 years so that we can obtain the mean motion of the Sun according to years of the Christians. For in 20 years of the equinoctial point nothing must be found according to signs or degrees or minutes. The 0;9° accordingly are placed [in the table] so one can obtain the Sun's motion in 20 years of the Christians. These 0;9° are the amount by which 20 years of the equinoctial point are surpassed by 20 years of the Christians.

II 〈De compositione tabularum〉

〈II.i〉

O 122r Tabulas compositurus hoc ordine procedes. Inventionem et tabulas alicuius precedentis assumes. Et quo die cuius mensis et quoti anni secundum ipsum Sol intravit iuncturam circulorum comperies, quota etiam hora diei et 〈quoto〉 minuto. Id etiam et tempore tuo comperies, deinde distantiam temporis intra utramque inventionem in annis secundum iuncturam, diebus, horis, minutis. Et totum spatium annorum interiacentium solves in dies, multiplicando scilicet numerum annorum inventorum in dies integros unius anni. Et dies quot provenerint ex quarta diei secundum Christianos, scilicet sex horis singulis annis redactis in dies, aggregabis predicto numero dierum. Et horas que sunt ultra dies integros servabis. Et totum numerum dierum collectum partieris super numerum annorum interiacentium. Que provenerint erunt anni dies. Et quod remanserit indivisum convertes in horas ducendo in 24, qui est numerus horarum diei. Et quod inde collegeris addes horis quas prius habebas et partieris iterum super numerum annorum predictorum. Que provenerint erunt hore que supra dies integros sunt. Et quod remanserit indivisum duces in 60 secundum numerum minutorum hore, ut illud reliquum convertas in minuta hore. Et minuta que inde collegeris addes minutis hore, si que prius habuisti. Et totum numerum iterum divide in predictum numerum annorum. Que provenerint erunt minuta hore, que pones cum diebus et horis prius collectis. Et si quid etiam ex hac partitione superfuerit, convertes in secunda hore ducendo in 60 et dividendo in predictum numerum annorum. Et que in parte venerint erunt secunda, que pones cum diebus, horis et minutis collectis. Et quot provenerint dies, hore, minuta, secunda erit tempus cursus Solis anni secundum iuncturam circulorum.

Et ad habendum revolutionem anni secundum gradus, vide quot hore super integros dies fuerint et quot desint ad complementum 6 horarum que diem faciunt [!]. Et pro singulis quaternis deficientium ad complementum

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3 Inventionem] Inventionum *O* ‖ et] *om. O* 4 assumes] sumes *C* ‖ cuius] cuiusque *O* 6 Id etiam et] ibidem *O* ‖ id] idem *a.c. C* ‖ tuo] suo *C* 8 interiacentium] interiacens *O* 9 numerum … in] in numerum annorum inventorum *C* 10 quot] qui *C* ‖ provenerint] proveniunt *C* ‖ diei] die *O* ‖ Christianos] Christianum *C* ‖ scilicet] p(?) *C* 13 partieris] partiens *O* ‖ numerum annorum] annorum numerum *C* 15 diei] dierum *O* 16 iterum] ita *C* 16–17 annorum predictorum] predictorum annorum *C* 19 inde collegeris] collegeris inde *C* 20 minutis] minuta *C* ‖ iterum] minuta *C* 21 numerum annorum] annorum numerum *O* ‖ provenerint] in parte venerint *C* 22 ex] in *C* 28 6 horarum] horarum 24 *O* 29 quaternis] horis *add. O* ‖ ad] de *C*

11 On the Construction of Tables

11.i

In order to construct tables you will proceed as follows. You will take the finding and tables of some predecessor. And you will ascertain the day, month, and year as well as the hour and minute of the day at which the Sun entered the equinoctial point according to him. You will also ascertain this in your own time. Next [you will ascertain] the time difference between both findings in terms of years according to the equinoctial point, days, hours, [and] minutes. And you will convert this whole intervening time span into days, by multiplying the number of years found by the complete days [contained] in one year. And you will add to this number of days the number of days that comes out of the quarter-day according to the Christians, that is, by converting into days the six hours that are [contained] in each year. And you will keep the hours that are left over besides the complete days. And you will divide the whole number of days thus gathered by the number of intervening years. What comes out [of this division] will be the days in a year. And what remains undivided you will convert into hours by multiplying it by 24, which is the number hours in a day. And what you have gathered from this you will add to the hours that you had obtained earlier, and you will divide it again by the number of the aforementioned years. What comes out of this will be the hours that are there besides complete days. And what remains undivided you will multiply by 60 according to the number of minutes in an hour, so as to convert this remainder into minutes of an hour. And the minutes you have gathered from this you will add to the minutes of an hour, if you had any to begin with. And you must again divide the whole number by the aforementioned number of years. What comes out of this will be the minutes of an hour, which you will place with the days and hours gathered earlier. And if something is left even after this division, you will convert it into seconds of an hour by multiplying it by 60 and dividing it by the aforementioned number of years. And what comes out of this division will be seconds, which you will place with the days, hours, and minutes [already] gathered. And the days, hours, minutes, [and] seconds that come out of this will be the time of the Sun's annual circuit according to the equinoctial point.

And to obtain the revolution of the year according to degrees, you must see how many hours there are besides complete days and how much is missing to complete 6 hours, which make up a day [!]. And for every four [minutes] that are missing to complete them, you will take one degree,

sumes unum gradum, quoniam in quatuor minutis hore recte unus gradus *O* 122^{v} | ascendit. Et quot inde collegeris gradus, tot minues a 90 gradibus, quos constat ascendere 6 horis. Et quot gradus remanserint, tot gradus circuli ascendunt supra 365 dies in revertendo Solem ad iuncturam, quia non integre ascendunt 90 gradus. Potius, sicut deest de 6 horis, sic deest de 90 gradus. Et quantum inveneris erit revolutio anni secundum gradus, scilicet ad iuncturam. Et ad habendum annos Christianorum, qui sunt secundum integram sextam, addes inventis annis quantum interest inter tot annos iuncture et tot annos Christianorum, et habebis annos Christianorum.

Sint inter inventionem Azarcheli et nostram 20 anni iuncture et quod ipse invenerit Solem intrare iuncturam Christi annis 1120 completis mense Martio, 14 die, horis duabus post meridiem completis. Et sit quod tu inveneris Solem eandem iuncturam intrare 14 die Martii, anno Christi 1140, et deesse ad completionem tot annorum Christianorum horas quatuor et duabus horis ante meridiem sit ingressus Solis ad iuncturam. Sunt igitur inter horam ab Azarchele inventam et horam a te inventam 20 anni iuncture et nihil supra. Sed ad complementum 20 annorum Christianorum desunt hore quatuor. Quibus completis completi sunt 20 anni Christi, quoniam anni Christi semper in quarto anno ad horam eandem revertuntur, ut si hic annus incipiat a prima diei, post quatuor annos completos incipiet annus ab hora prima diei. Unde provenit ut cum Sol sit inventus ab Azarchele in iunctura *C* 69^{r} duabus horis | post meridiem ab illa secunda hora 20 anni compleantur duabus horis post meridiem. Invento itaque a te Sole in iunctura duabus horis ante meridiem 20 anni iuncture completi sunt, et nihil supra, et ad completionem, ut diximus, totidem annorum Christianorum desunt hore quatuor.

Oportet itaque ut totum tempus inter utramque inventionem in dies et horas resolvatur, ut sciatur quot dies et hore supra intersint. Ductis igitur 365 diebus anni in 20 annos habebis 7300, quibus appones dies qui excrescunt

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30 quoniam] solis *C* ‖ quatuor minutis] minutis quatuor *O* ‖ unus] unius *C* 31 quot] tot *C* ‖ inde collegeris gradus] gradus inde collegeris *C* 32 ascendere] in *add. C* ‖ gradus] inde *add. C* 34 sic] sicut *O* 35 inveneris] minueris *C* 37 sextam] satam(?) *O* 37–38 annos … annos] annorum *C* 39 Azarcheli] Ezarchel *C*; Azarcelli *O* ‖ iuncture] inventure *O* 40 ipse invenerit] invenerit ipse *C* ‖ Solem] *om. O* 41 Martio] Martii *C* ‖ completis] *om. O* ‖ tu] cum *O* 43 completionem] *om. O* ‖ horas] omissis *C* ‖ quatuor] 4 *C* 44 ad] *om. O* 45 Azarchele] Azarkello *O* ‖ a te inventam] ante iuncturam *O* ‖ 20] 2 *C*; 11^{o} *O* 47 anni Christi] *om. C* 48 horam eandem] eandem horam *O* ‖ ut] et *a.c. C*; *O* 49 incipiet] incipit *C* 50 Azarchele] Azarkello *O* 50–51 in … meridiem] duabus horis post meridiem in iunctura *O* 51 secunda … compleantur] hora secunda 20 compleantur anni *C* 52 a … sole] sole a te *C* ‖ duabus] 4 *C*; IIII^{or} *O* 53 meridiem] *om. O* ‖ 20] 40 *C* ‖ completi] expleti *O* 53–54 completionem] complementum *C* 56 resolvatur] solvatur *C*

because four minutes of the hour correspond to one degree of right ascension. And you will subtract the resulting number of degrees from 90°, which ascend in 6 hours. And the number of degrees that remain is how many degrees ascend in addition to 365 days before the Sun returns to the equinoctial point. For the 90 degrees do not ascend in their entirety. Rather, what is missing from 6 hours is also missing from 90°. And the amount found will be the revolution of the year (i.e., with respect to the equinoctial point) according to degrees. And to obtain years of the Christians, which are [reckoned] according to the completed sixth [hour], you will add to the years you have found the difference between this many years of the equinoctial point and this many years of the Christians, and you will have years of the Christians.

Let us assume that there are 20 years of the equinoctial point between Azarquiel's finding and our own and that he found the Sun to enter the equinoctial point when 1120 years of Christ were complete, on 14 March, with two hours after noon completed. And let us assume that you have found the Sun to have entered the same equinoctial point on 14 March in the year of Christ 1140 and that four hours are missing to complete the same number of years of the Christians, and that the Sun entered the equinoctial point two hours before noon. There are, then, 20 years of the equinoctial point and nothing more between the hour found by Azarquiel and the hour you have found yourself. But there are still four hours missing to complete 20 years of the Christians. Once these have been completed, 20 years of Christ are complete, because the years of Christ always return to the same hour at the end of four years, such that if this year begins from the first [hour] of the day, after four years the year will [again] begin from the first hour of the day. Consequently, if Azarquiel found the Sun at the equinoctial point two hours after noon, the completion of 20 years from this second hour must come two hours after noon. And so, 20 tropical years, and nothing more, were completed when you found the Sun at the equinoctial point two hours before noon, and four hours are still missing to complete as many years of the Christians, as we have said.

We must, therefore, convert the whole interval between both findings into days and hours, to know how many days as well as hours are between them. If you accordingly multiply the 365 days in a year by 20 years, you will have 7300, to which you will add the days that arise from the hours that are left

O 123^{r} ex horis que supersunt singulis annis | ad complementum reditus ad iuncturam. Sunt autem quatuor dies et 20 hore. Et habebis 7304 dies et 20 horas. Hii sunt ergo dies interiacentes inter utrumque inventionem et hore, que sunt in 20 annis iuncture. Ut igitur inde deprehendas quantus sit cursus Solis in uno anno, divides predictos dies et horas in totum numerum annorum, scilicet 20, ut scias quota pars pertineat ad annos singulos. Cum ergo dies diviseris in predictum numerum, provenient in parte 365 dies. Et quatuor supersunt, quos solves in horas ducens in 24. Et habebis 96 horas. Quas adicies predictis 20 horis et fient hore 116. Quas cum divides predictis annis 20, provenient singulis annis in parte 5 hore. Quas addes priori collectioni et habebis dies 365 et horas 5 et supersunt 16 hore dividende. Quas ut dividas annis predictis duces in 60 et facies minutas hore. Provenient 960 minuta hore. Quas dividens predictis 20 annis dabis singulis 48 minuta. Et nihil superest. Que 48 superaddes priori collectioni et habebis dies 365 et horas 5 et 48 minuta hore, qui erunt annuus Solis cursus secundum iuncturam iuxta utramque inventionem.

Et inde habebis revolutionem annuam minutis a 90 gradibus secundum quartam 12 minuta que desunt ad complementum 60, scilicet trium graduum, quoniam ad trium graduum ascensum pertinent 12 minuta hore. Erit igitur revolutio anni emensio totius circuli, id est 360 graduum, et 87 graduum secundum inventionem utramque.

Unde tabulas compositurus uni anno subicies in eadem linea numerum signorum et graduum et minutorum et secundorum que percurrit Sol in diebus anni inventis secundum iuncturam 365. Et ut facias annos secundum compotum Christianorum, qui magis communis est, videbis quantum Sol percurrat in quatuor horis, que sunt differentia 20 annorum iuncture completorum ad totidem annos Christi, et tantundem adicies ad perficiendum annos Christi 20. Sunt autem 9 minuta et 51 secunda secundum inventionem *O* 123^{v} tuam, que subiciende sunt | in linea annorum 20, cum secundum iuncturam nihil in signis, gradibus, minutis, secundis inveniri debeat.

Sic autem provenit secundum exemplum, quod causa evidentie posuimus. Quia secundum inventionem recte omnino provenientem erit annus

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59 et habebis] habebis igitur *C* 62 scilicet] *om. O* 63 ut] et *CO* 65 24] viginti quatuor *C* 66 cum] etiam *C* ‖ predictis … 20] 20 annis predictis *C* ‖ provenient] ergo *add. C* 67–68 et … 365] Habebis 365 dies *C* 68 16] 14 *C* 69 provenient] ergo *add. C* 70 predictis] *om. C* ‖ superest] supra erit *C* 71 5] 4 *C* 72 annuus] annus *C* 74 minutis] minues *C* 75 12] 4812 *C* ‖ que desunt] quod est *C* 77 igitur] *om. C* ‖ id est] *om. C* 77–78 et 87 graduum] *om. C* 79 subicies] subicias *O* 80 et^{2}] *om. O* 81 iuncturam] *om. C* ‖ annos] *om. C* 84 tantundem] totidem *O* 85–86 Sunt … 20] *om. per hom. C* 85 51] linea *O*

over in each year to complete the return to the equinoctial point. These are 4 days and 20 hours. And you will have 7304 days and 20 hours. These, then, are the days and hours that lie between both findings, which is [their number] in 20 years of the equinoctial point. In order to derive from this the Sun's motion in one year, you will divide the aforementioned days and hours by the whole number of years (i.e., by 20) to find out how much of it pertains to individual years. If you accordingly divide the days by the mentioned number, this will result in 365 days. And there is a remainder of 4, which you will convert into hours by multiplying them by 24. And you will have 96 hours. You will add these to the aforementioned 20 hours and they make 116 hours. If you divide these by the aforementioned 20 hours, this will result in 5 hours for each year. You will add these to the previous sum and have 365 days and 5 hours with 16 hours left to divide. To divide these by the aforementioned years, you will multiply them by 60 and make minutes of an hour. This results in 960 minutes of an hour. You will divide these by the aforementioned 20 years, giving 48 minutes to each. And there is no remainder. You will add these 48 to the previous sum and will have 365 days, 5 hours, and 48 minutes of an hour, which will be the [length of] the Sun's annual motion according to the equinoctial point as indicated by the two findings.

And you will obtain from this the annual revolution by subtracting from the 90° corresponding to the quarter-day the 12 minutes that are missing to complete 60, which are 3°, because 12 minutes of an hour are equivalent to an ascension of 3°. According to the two findings, the revolution of the year will accordingly consist in the completion of the whole circle (i.e., 360°) and 87°.

In order to construct tables you will accordingly write next to one year in the same line the number of signs, degrees, minutes, and seconds that the Sun traverses in 365 days of the found year according to the equinoctial point. And to make years according to the reckoning of the Christians, which is more common, you will look at the amount the Sun traverses in 4 hours, which are the difference between 20 completed years of the equinoctial point and as many years of the Christians; and this is what you will add to complete 20 years of Christ. According to your finding this amount is 0;9,51°, which must be written next to the line for 20 years, whereas according to the equinoctial point there would have to be nothing [in the columns] for signs, degrees, minutes, [and] seconds.

But this is the result that comes out of this example, which we have presented to make things easier to understand. For if the finding is made with complete accuracy, the resulting solar year according to the equinoctial

Solis secundum iuncturam 365 dies et 5 hore et 49 minuta, deficientibus tantum 11 minutis ad complendum 60 et ad completionem hore sexte quam in anno Christianorum assignamus. Ars autem tradita vera est et impermutabilis et secundum exemplum provenit ut diximus, si sic quidem esset ut in exemplo posuimus.

⟨II.ii⟩

Comperto autem quantum Sol percurrat in anno secundum iuncturam et quot diebus et horis et minutis ac secundis cursum suum expleat, comperias quantum in uno die et hora una illius cursus perficiatur hoc modo. Dies omnes anni in horas convertes multiplicando in 24. Et ipsi multiplicationi addes horas que supra dies integros sunt. Et provenient 8765 hore. Quas iterum ducens in 60 convertes in minuta. Et habebis adiectionem 48 minutorum, que sunt supra horas. Et erunt 525948 minuta. Item numerum graduum circuli convertes in minuta gradus ducendo in 60. Et provenient 21600. Deinde totum convertes in secunda ducendo in 60. Et provenient 1296000 secunda. Que partiens in numerum minutorum in que solute sunt dies et hore dabis in parte 2, que sunt minuta. Et quot secunda remanserint indivisa convertes in tertia ducens in 60. Et quot collegeris erunt tertia. Que iterum dividens in predictum numerum horarum dabis 27, que sunt secunda. Habes ergo ex hac partitione 27 secunda. Iterum quot remanserint tertia indivisa duces in 60 ut convertas in quarta. Que iterum dividens in predictum numerum horarum dabis in parte 52, que erunt tertia. Et quot remanserint quarta indivisa convertes in quinta ducens in 60. Et totum divides in numerum primum et facies sic quarta. Et deinceps usque in decima poteris procedere. Sed sufficiant tertia. Que si addideris secundis et minutis prius collectis habebis 2 minuta, 27 secunda et 52 tertia que singulis horis deputantur.

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90 dies] *om. C* 91 complendum] complementum *C* ‖ completionem] complementum *C* ‖ hore sexte] sexte hore *C* 92 assignamus] assignavimus *C* 93 sic] id *O* 96 percurrat] percurrerat *O* 97 et^{1}] *om. O* ‖ ac] et *C* ‖ suum] *om. O* 98 hora una] in una hora *C* ‖ perficiatur] perficiat *C* 99 convertes] convertas *O* 101 iterum] item *C* ‖ ducens … minuta] convertes in minuta ducens in 60 *C* ‖ adiectionem] cum adiectione *C* 102 supra … erunt] super horas *C* 104 21600] 24300 minuta *C* 105 que] quas *CO* ‖ partiens] partieris *C* ‖ que solute] quas soluti *C* 106 sunt] *om. C* 107 tertia^{1}] tertias gradus *C* 109 ex … secunda] 27 secundas ex hac partitione *C* ‖ iterum] item *C* 110 iterum] item *C* 111 in] super *C* ‖ horarum] *om. O* ‖ quot] *om. C*; que *O* 112 remanserint] remanebunt *C* ‖ convertes] convertas *C* ‖ ducens] ducendo *C* 112–113 divides] duces *C* 113 facies … quarta] sic facies sextas *C* 114 sufficiant] sufficiunt *C* 115 minuta] et *add. C* ‖ 27] 22 *C* 116 deputantur] computantur *O*

point will be 365 days, 5 hours, and 49 minutes, such that exactly 11 minutes are missing to complete 60 and to complete the sixth hour that we allot to one year of the Christians. The method, however, that has been described [above] is true and unchangeable and the example produces the result we have given, provided things are as we have assumed in the example.

II.ii

Having found the [distance] that the Sun traverses in one year according to the equinoctial point and how many days, hours, minutes, and seconds it takes to finish its course, you may use the following method to ascertain how much of this course it completes in one day and in one hour. You will convert all days of the year into hours by multiplying them by 24. And you will add to the product the hours that remain besides whole days. And the result will be 8765 hours. You will convert these in turn into minutes, by multiplying them by 60. And you will have another 48 minutes that remain besides the hours. And the result will be 525,948 minutes. You will also convert the number of degrees in the circle into minutes by multiplying them by 60. And the result will be 21,600. Next you will convert it all into seconds by multiplying it by 60. And the result will be 1,296,000 seconds. Dividing these by the number of minutes into which the days and hours have been converted, you will give 2, which are minutes, to each. And you will convert the seconds that remain undivided into thirds by multiplying them by 60. And the number gathered from this will be thirds. Dividing these in turn by the aforementioned number of hours you will give 27, which are seconds. You will accordingly have 27 seconds from this division. You will again multiply the thirds that remain undivided by 60 to convert them into fourths. Dividing these in turn by the aforementioned number of hours you will give 52, which are thirds, to each. And you will convert the fourths that remain into fifths by multiplying them by 60. And you will divide the whole by the first number and thereby make fourths. And you will be able to continue in this way up to tenths, though thirds shall be enough. If you add them to the seconds and minutes gathered previously, you will have 0;2,27,52° that are assigned to each hour.

Inventum est que portio graduum circuli quos Sol perficit in anno secundum iuncturam perficiatur una hora, scilicet 2 minuta et 27 secunda et 52 tertia. | Unde, quoniam 52 tertia fere perficiunt unum secundum, Sarraceni apposuerunt uni hore 2 minuta et 28 secunda, omissis tertiis que sic perficiunt unum secundum. Quarta et quinta et ceteras fractiones omnino omiserunt. Et magnum est, ut ait Ptolomeus, si etiam minuta integre collegerimus. Inde est quod in linea hore unius invenies in tabulis 2 minuta et 28 secunda ascripta. Et ut inde colligas quantum ad diem unum pertineat duces minuta et secunda uni hore deputata in 24, quot sunt hore que diem faciunt. Et inde colliges 59 minuta et 8 secunda, que Sol uno die perficit. Que fere equaliter uni gradui Soli competunt. Unde in tabulis ascripta invenies uni diei 59 minuta et 8 secunda. O 124^{r}

Ut etiam comperias que portio unum minutum hore contingat, minuta que ad horam unam pertinent in secunda convertes et aggregabis secundis. Item eadem secunda, si volueris, in tertia. Et totam collectionem divides in 60, qui numerus est minutorum hore. Et quod in parte venerit uni minuto deputabitur et uni minuto hore in tabulis ascribetur, duplum duobus, triplum tribus, et deinceps. Sic autem et in diebus duplum eius quod ascribitur uni diei ascribes duobus, triplum tribus, et deinceps. In horis similiter usque ad 24, in diebus vero usque ad 30 et in punctis horarum usque ad 60.

⟨ii.iii⟩

Quoniam tabule habent initium ab initio mensium, quedam a Ianuario, quedam a Martio, quedam ab Octobre, prout fuerit voluntas et ratio componentium, hac ratione oportet procedere. Requires qua hora cuius diei et cuius mensis Sol intrat in capite Arietis per astrolabium completum secundum artem alibi traditam per altitudinem | meridianam et latitudinem terre vel id ipsum per tabulas aliquas comperies. Ponatur itaque ut duabus horis post C 69^{v}

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117 graduum circuli] circuli gradus *O* 118 27] 29 *C*; *om. O* ‖ secunda] secundis *C* ‖ 52] 59 *CO* 119 tertia] tertiis *C* ‖ quoniam] quia *O* ‖ 52] 59 *CO* 119–121 Sarraceni … secundum] *om. per hom. O* 121 fractiones] fracturas *C* 122 omiserunt] dimiserunt *C* 122–123 collegerimus] colligimus *O* 123 hore unius] unius hore *C* ‖ invenies] invenis *C* 124 ascripta] scriptas *C* 125 minuta] vel puncta *add. s.l. O* ‖ sunt … que] scilicet hore *C* 127 equaliter … competunt] equivalent uni gradui *C* 129 minutum] vel punctum *add. s.l. O* 130 horam unam] unum diem *C*; diem unum *O* ‖ in … convertes] convertes in secundas *C* convertes] convertas *O* ‖ secundis] et *add. C* 131 eadem secunda] *om. C* 132 numerus est] est numerus *C* ‖ minutorum] vel punctorum *add. s.l. O* 133 minuto] *om. C*; puncto sive minuto *O* 136 et … 60] in horarum minutis usque ad 60 progredieris *C* 138 habent … quedam] quedam habent inicium mensium *C* 139 Octobre] Octobri et *C* ‖ voluntas et ratio] ratio et voluntas *C* 140 oportet procedere] procedere oportet *C* 141 intrat] intret *C* ‖ in capite] caput *C* 143 itaque] igitur *C*

What has been found is how much of the degrees of the circle that the Sun completes in a year according to the equinoctial point is completed in one hour, namely, 0;2,27,52°. Since 52 thirds nearly complete one second, the Saracens assigned to one hour 0;2,28° while omitting the thirds, which thus complete one second. The fourths, fifths, and the other fractions they omitted entirely. And it is a great thing, as Ptolemy said, for us even to gather the minutes in their entirety. This is why you will find 2 minutes and 28 seconds written in the line for one hour in the tables. And to gather from this the amount for one day, you will multiply the minutes and seconds assigned to one hour by 24, which is the number of hours that makes one day. And from this you will gather 0;59,8°, which the Sun completes in one day. These are nearly the same as one degree for the Sun. You will according find 59 minutes and 8 seconds written next to one day in the tables.

In order to ascertain also the amount that corresponds to one minute of the hour, you will convert the minutes pertaining to one hour into seconds and add them to the seconds. [You will] also [convert], if you wish, these seconds into thirds. And you will divide the whole result by 60, which is the number of minutes in an hour. And what comes out of the division will be assigned to one minute and ascribed to one minute in the tables, twice this amount to two, three times [this amount] to three, and so on. The same [will be done] for hours up to 24, but for days up to 30 and for minutes of an hour up to 60.

II.iii

Since the tables take their beginning from the beginning of the months—some from January, some from March, some from October, depending on the preference and reasoning followed by those who compose them—, one must proceed as follows. You will seek out in which hour of which day and month the Sun enters the head of Aries by using a complete astrolabe according to a method that has been handed down elsewhere, which involves the [solar] noon altitude and terrestrial latitude—or you will ascertain the same by means of tables. Let us assume, then, that the Sun enters

meridiem 14 die Martii intret Sol in capite Arietis et ita per artem traditam inveneris. Et quoniam Sol totum circulum est mensus, nihil in tabulis habebis in signis, gradibus, minutis, secundis. Solves tamen in equivalens, id est in 11 signa, 29 gradus, 59 minuta, 60 secunda, que redacta ad principium perficiunt 12 signa, que integre complevit Sol ab initio anni, quoniam, ut dictum est, totum circulum percurrit.

Erit autem hic ordo ut per directum cursum invenias medium cursum illius hore, deinde cursum medium in meridie precedente. Quo invento invenies arte simili cursum medium quotlibet horis, diebus, mensibus, annis preteritis. | *O* 124$^{\text{v}}$ Econverso autem operabis in inveniendo cursum medium per directum inventioni cursus directi per medium. Minues itaque a cursu directo locum altum Solis, id est ab 11 signis, 29 gradibus, 59 minutis, 60 secundis 2 signa, 27 gradus, 2 minuta, qui est locus altus. Quod remanserit erit pars Solis, scilicet 9 signa, 2 gradus, 58 minuta. Et quoniam ad prope prius docenda est inventio, pro 58 minutis sumes 1 gradum, quem addes 2 gradibus. Et erit pars 9 signa, 3 gradus. Sumes deinde directionem ipsi adiacentem in tabulis, id est unum gradum, 58 minuta, 47 secunda. Et quoniam pars est plus 6 signis, minues directionem a cursu directo, sicut ad inveniendum directum per medium oportet addere, quoniam hic retrocedendum est ad inveniendum per posteriora priora. Et si pars esset minus 6 signis, oporteret addere. Remanet itaque post minutionem 11 signa, 28 gradus, 1 minutum. Et hoc erit medius cursus ad prope in hora predicta.

Cuius cursus ad prope inventi invenies directionem hoc modo. Minues ab eo locum altum. Relinquitur pars: 9 signa et 59 minuta. Et quoniam 59 minuta ad prope faciunt unum gradum, intrabis per 9 ⟨signa⟩ et 1 gradum. Et sumes directionem adiacentem, scilicet unum gradum, 59 minuta, 5 ⟨secunda⟩. Et quoniam pars est plus 6 signis, addes directionem inventam pro solito et ratione directionis. Est enim hec via dirigendi cursui mediato.

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144 in capite] caput *C* 145 mensus] emensus *C* 146 solves] solvens *C* 147 11] 11^{cim} *O* ‖ ad principium] *om. C* 148 que ... quoniam] integre que complevit si ab initio Arietis *C* 151 cursum medium] medium cursum *O* 152 diebus, mensibus] mensibus et diebus *C* 153 econverso] equos *O* ‖ cursum medium] cursu medio *C* 154 directi] directionis *O* ‖ directo] directionis *O* 155 altum] alium *O* 156 2] 52 *C* ‖ qui ... altus] qui est altus *mg. O* ‖ erit] *om. O* ‖ pars] locus *C* 157 58] 57 *O* 157–158 docenda est] dicenda *C* 158 58] 59 *C*; 57 *O* ‖ 1] unum *C* ‖ quem] que *C* ‖ 2 gradibus] duobus gradus *C* 160 58] 59 *C* ‖ minuta] et *add. C* ‖ 47] 41 *O* 161 directionem ... directo] a cursu directionis *O* 162 retrocedendum] introducendum *O* 163 priora] prius *add. C* ‖ minus] a *add. C* 164 minutum] *add.* 13 secunda *C* 165 medius cursus] cursus medius *C* 167 locum] *om. O* ‖ et ... minuta] 0.59.13 *C* 168 minuta] *om. O* 168–169 per ... gradum] *om. C* 169 minuta] *om. C* 170 5] per 95 *C*; 8 *O*

the head of Aries two hours after noon on 14 March and that you find this to be the case using the method in question. And since the Sun has [then] traced out the whole circle, the tables [will show] you 0s 0;0,0°. You will nevertheless convert this into its equivalent, namely, 11s 29;59,60°. If reduced to the first [unit], these amount to 12 signs, which the Sun has fully completed at the start of a year, because it has traversed the whole circle, as has been said.

The sequence [of steps to follow], however, will be for you to find from the true motion the mean motion at this hour, [and] afterwards the mean motion at the previous noon. Having found this, you will find by the same method the mean motion in any number of preceding hours, days, months, [or] years. But to find the mean motion from the true motion, you will operate in reverse to the way one finds the true motion from the mean one. Subtract the solar apogee from the true motion, that is, 2s 27;2° (which is the apogee) from 11s 29;59,60°. What remains will be the anomaly of the Sun, namely, 9s 2;58°. And since one must first teach how to find [the mean motion] in an approximate way, you will take 1° for 0;58°, adding it to 2°. And the anomaly will be 9s 3°. You will next take the correction that is adjacent to it in the tables, which is 1;58,47°. And since the anomaly is greater than 6 signs, you will subtract the correction from the true motion, just as one must add it to find the true from the mean motion, because here one must go in reverse to find the earlier from the later. And if the anomaly were less than 6 signs, one would have had to add [the correction]. The remainder after this subtraction is therefore 11s 28;1°. And this will be the approximate mean motion at the aforementioned hour.

You will find the correction that corresponds to this approximate motion via the following method. You will subtract the apogee from it. What remains is the anomaly: 9s 0;59°. And since 0;59° are nearly 1°, you will enter [the table] with 9s 1°. And you will take correction adjacent to it, which is 1;59,5°. And since the anomaly is greater than 6 signs, you will add the correction thus found in the usual way by which the correction is calculated. For this is the way by which the mean motion is rectified. And the result will be 0s

Et occurret nihil in signis, gradibus, minutis et 18 ⟨in⟩ secundis. Et interest inter hunc locum directum et primum locum directum 18 secunda. Et quoniam hec plus sunt a loco omnino directo provenientes secundum cursum medium ad prope sumptum, minues hec secunda a cursu medio. Et si minus essent, addendi essent. Quoniam ista directione prius habita superabundant eo quod cursus medius ad prope sumptus est. Nec potest omnino recte inveniri per cursum directum, quia nesciebatur quanta esset directio. Que ergo invente sunt superabundare a recto minuende sunt, quia iam certum est quantum superabundet, eo quod non potuit cursus medius omnino recte sumi, sed ad prope tantum sumptus est. Et quod reliquum fuerit minuto superabundante est recte sumptus cursus medius. Ex quo provenire deberet locus directus primus quem invenisti ratione directionis. Quod si dirigas partem directionis minuendo locum altum et cetera operando, occurret locus rectus quem primum invenisti. Erit ergo cursus medius recte sumptus 11.28.0.55. Quem si dirigas habebis cursum directum Solis in capite Arietis, id est 11.29.59.60, que sunt 12 signa, et occurret nihil in signis, gradibus, minutis, secundis, et in tabula 0.0.0.0.

Habito itaque cursu medio duabus horis post meridiem inde minues quantum Sol percurrit in duabus horis et habebis cursum eius medium in precedenti meridie. Est autem cursus ipsius duabus horis quatuor minuta *O* 125$^{\text{r}}$ et 56 secunda. Que cum minueris ab 11.28.0.55 remanent 11.27.55.59. | Et hoc erit cursus mediatus in meridie preterita in 14 die Martii. Et si volueris habere cursum mediatum in primo die Martii minues cursum 14 dierum, quantum scilicet inveneris in linea 14 dierum. Et suscipies medium cursum in primo die Martii, reliquum scilicet post minutionem. Et ut habeas cursum medium in initio cuiuslibet mensis precedentis sumes cursum dierum interiacentium et minuas predicto modo a cursu invento. Reliquum erit cursus mediatus in die quesito. Ut si scire velis cursum mediatum in primo die

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172 occurret] occurrit *C* ‖ secundis] secundum 0.0.0.18 *C* 173 directum] directionis *O* ‖ et] loci *add. O* 173–174 quoniam] quia *C* 174 a] de *C* 176 addendi essent] *om. O* ‖ ista] a recta *add. C* 177 quod] quia *O* ‖ ad ... nec] sumptus ad prope non *O* ‖ recte] *om. O* 178 quia] quin *C* ‖ nesciebatur] nesciebant *O* 179 minuende] minuendo *O* 180 cursus ... recte] medius cursus recte omnino *C* 181 tantum] *om. C* 182 superabundante] superhabundare *O* ‖ cursus medius] medius cursus *C* 182–183 deberet] debuit *CO* 183 quod] quem *O* 183–184 dirigas] redigas *O* 184 et] *om. O* 185 recte] rectus *O* 186 11.28.0.55] *om. O* 187 11.29.59.60] 11 signa, 29 gradus, 59 minuta, 60 secunda *C* ‖ que ... signa] *mg. O* ‖ signis] *om. C* 188 0.0.0.0] circuli *C* 192 11.28.0.55] 11 signis 29 gradus minutio *O* ‖ 11.27.55.59] 11 signa, 29 gradus, 55 minuta, 4 secunda *O* 193 preterita] predicta *O* 195 medium cursum] cursum medium *C* 196 minutionem] meridiem *O* 197 medium] vel mediatum *add. O* 198 minuas] minues *C*

0;0,18°. And there is a difference of 18 seconds between this true position and the first true position. And since the result that arises according to the approximate mean motion is greater than the entirely true position, you will subtract these seconds from the mean motion (and if [the result] were less, they would have to be added). For these are an excess in the correction that was had earlier, owing to the fact that the mean motion was approximated, nor can it be derived with full accuracy from the true motion, seeing as the amount of the corresponding correction was unknown [at first]. The excess that has been found with respect to the correct amount (for it is now certain how much [this excess] is) must hence be subtracted, considering that the mean motion could not be derived with full accuracy, but was only approximated. And what remains after subtracting the excess is the accurately determined mean motion. From this one ought to be able to derive via the method of correction the true position that you found at the beginning, such that if you correct the anomaly of the correction by subtracting the apogee and performing the other operations, the result will be true position that you find at the beginning. The correctly derived mean motion will accordingly be 11s 28;0,55°. If you apply the correction to this you will have the true motion of the Sun at the head of Aries, namely, 11s 29;59,60°, which are 12 signs, and there will be no signs, degrees, minutes, [or] seconds, and the table [will show] 0s 0;0,0°.

And so, once you have the mean motion at two hours after noon, you will next subtract the amount the Sun traverses in two hours and you will have its mean motion at the previous noon. But its motion in these two hours is 0;4,56°. If you subtract these from 11s 28;0,55° there remain 11s 27;55,59°. And this will be the mean motion at the preceding noon on 14 March. And if you wish to have the mean motion on 1 March, you will subtract the motion in 14 days, that is, the amount you find in the line for 14 days. And as the remainder from this subtraction, you will receive the mean motion on 1 March. And in order to obtain the mean motion at the beginning of any preceding month, you will take the motion of the intervening days and subtract it in the aforementioned way from the motion found. What remains will be the mean motion on the day that is sought. So if you wish to find the mean motion

Ianuarii, numera quot dies intersint a primo die Ianuarii ad 14 diem Martii. Invenies 73 dies. Et requires cursum mediatum in tot diebus considerans quantum adiaceat in tabula mensium duobus mensibus, Ianuario scilicet et Februario, quorum unus habet 31 dies, alter 28. Inde habebis quantum adiaceat 59 diebus. Et sumes quantum adiaceat reliquis diebus 14 in tabula dierum et aggregabis. Et minues a cursu invento. Quod provenerit erit cursus Solis in principio Ianuarii. Similiter suscipies cursum quotlibet diebus preteritis observans quot menses interfuerint. Et quot dies habuerint tantum sumes de cursu dierum interiacentium ex numeris adiacentibus illis mensibus. Reliquum autem comperies in tabula dierum.

Et ut invenias cursum mediatum in anno uno vel pluribus usque ad 20 minuas quantum inveneris in linea tot annorum a cursu invento in 14 die Martii et residuum erit cursus mediatus in initio sumptorum annorum. Quod si minor fuerit quam ut ab ipso possis minuere, addes 12 signa. Et cum dirigere volueris cursum mediatum inventum in quotlibet diebus, mensibus, annis transactis, quoniam minuendus est locus altus qui movetur quantum et stelle fixe, minues a loco alto presentis temporis quantum crescit in tanto tempore et cum illo postea diriges.

Si autem cursum mediatum volueris invenire initii 40 annorum, duplica quod inveneris 20 annorum et tantum minues. Si initii 60 annorum, triplica cursum 20 annorum. Et quotiens vicenos annos sumere volueris, totiens ducies cursum 20 annorum. Et minues ut supra et habebis cursum medium initio tot annorum quot sumpseris. Quod si cursum mediatum initii annorum Christi usque ad presens tempus scire volueris, quotiens inveneris vicenos annos, totiens sumes et minuta que inveneris ascribi 20 annis. Et ex minutis aggregatis facies gradus et quod provenerint gradus servabis. Et *C* 70$^{\mathrm{r}}$ similiter, si quot | minuta superfuerint ultra compositionem graduum servabis. Et si quot fuerint supra vicenos, addes unum annum et tot annorum cursum mediatum suscipies in tabula annorum expansorum et aggregabis gra-

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201 considerans] considera *C* 202–203 Ianuario … Februario] Martii scilicet et Aprilis *C* 203 unus] primus *C* ‖ 28] 30 *C* 204 59] LXI *C* ‖ 14] scilicet 13 *C* 206 solis] medius *s.l. O* 206–207 suscipies … preteritis] cursum mediatum quotlibet diebus preteritis suscipies *C* 207 observans] in *add. del. C*; ut *add. O* 208 sumes] assumas *C* ‖ adiacentibus] interiacentibus *a.c. C; O* 209 comperies] comperias *C* 210 uno] *om. C*; 1 *O* 212 sumptorum annorum] annorum sumptorum *C* 213 ut] *om. C* 215 annis] *om. O* 218 invenire] in *add. O* 218–219 40 … initii] *om. per hom. O* 219 60] tripli, id est 60 *C* 220–221 et … annorum] *om. per. hom. O* 221 et] *om. O* 222 initio] *om. O* 223 usque] *om. O* ‖ inveneris] minueres *O* 224 que] quas *CO* ‖ inveneris] memineris *O* 225 facies gradus] gradus facies *C* ‖ gradus] 6 *C* 226 quot] tot *O* ‖ graduum] gradus *O* 227 fuerint] *om. C* 228–229 aggregabis gradibus] acgrega diebus *O*

on 1 January, count the number of days between 1 January and 14 March. You will find 73 days. And you will seek the mean motion in this many days by considering the amount that in the table for months is adjacent to two months, namely, January and February, of which one has 31 days, the other 28. From this you will get the amount corresponding to 59 days. And you will take the amount that in the table for days is adjacent to the remaining 14 days and add it. And you will subtract [the sum] from the motion that has been found. The result will be the Sun's motion at the beginning of January. In the same way you will receive the motion in any number of preceding days by considering how many intervene. And depending on how many days they have, you will take the numbers adjacent to these months to get the motion of this many intervening days. The rest, however, you will find in the table for days.

And in order to find the mean motion for one year or for several [years] up to 20, you must subtract the amount you find in the line for this many years from the motion you have found on 14 March and the remainder will be the mean motion at the beginning of the years that have been taken. If there is too little for a subtraction to be made, you will add 12 signs. And if you wish to correct the mean motion that has been found for a given number of days, months, [or] years in the past, because this requires subtracting the apogee, which moves at the same rate as the fixed stars, you will subtract from the apogee at the present time the amount by which it increases in this time span so you can use it afterwards for the correction.

But if you wish to find the mean motion at the beginning of 40 years, double what you find for 20 years and you will subtract as much. If [you wish to find this] at the beginning of 60 years, multiply the motion in 20 years by three. And whatever multiple of 20 years you wish to take, you will multiply the motion in 20 years accordingly. And you will subtract in the same way as above and you will have the mean motion at the beginning of as many years as you have taken, such that, if you wish to know the mean motion from the beginning of the years of Christ to the present time, you will take the minutes you find written next to 20 years as many times as you have found 20 years. And you will make degrees from the accumulated minutes and keep the result as degrees. And in the same vein you will keep however many minutes are left after degrees have been made. And if there are [any years] left besides multiples of 20, you will add a year and receive the mean motion of the corresponding number of years in the table of expanded years and add it

O 125$^{\mathrm{v}}$ dibus et minutis | prius susceptis et totam summam minues a cursu mediato initii mensis Ianuarii, quem inveneris prius minuendo a cursu mediato in 14 die Martii cursum medium dierum interiacentium. Et quod reliquum fuerit post minutionem a cursu medio initii Ianuarii proximi tempore presenti erit medius cursus in initio Ianuarii proximi post nativitatem domini nostri Ihesu Christi.

Et quoniam nativitas ipsius precessit Ianuarium 7 diebus, cursum medium tot dierum sumes in tabula dierum. Quem minues a medio cursu Ianuarii. Et occurret tibi cursus medius natalis Christi in initio 7 dierum precedentium initium Ianuarii. Et quoniam secundum tabulas initia dierum et mensium sunt a meridie diei Christianorum et secundum communem usum—ut cum communis usus habeat initium Martii ab ortu Solis et diem tunc dicat incipere, secundum tabulas habet initium diei et mensis in meridie proxima post ortum Solis in eadem die—, si natale fuerit in principio diei vel anni secundum Solis ortum, cursus tot horarum quot sunt a meridie minuatur ab ipsius meridiei cursu et occurret cursus mediatus quem queris in nativitate domini. Similiter omnes cursus mediati, si regulam datam observaveris, sine omni defectu occurrent. Quod si direxeris, occurrent loca luminarium et planetarum directa in eadem nativitate.

Tabule autem nostre sunt secundum tabulas Assophii. Et initium faciunt anni a Martio, a prima scilicet meridie diei in qua secundum communem usum dicitur Martius intrare. Quas imiteris tabulas compositurus. Et quod vides ascriptum primo numero annorum Christi, scilicet in prima linea tabule, est cursus mediatus prime diei Martii. Que meridies est principium diei, mensis et anni secundum tabulas et est finis precedentium annorum tamquam si in tabulis scriberetur "tot annis Christi completis in meridie Martii intrantis, que est principium anni sequentis, mensis et diei, erit cursus medius in tot signis, gradibus, minutis, secundis supputatis ab initio Arietis." Quia sicut Martius fit anni initium secundum tabulas istas et mensis, sic Aries habetur pro initio signorum. Et qui faciunt initium anni sui in Octobri faciunt Libram initium signorum. Et sicut inter primam lineam et secundam differentia est 20 annorum, sic in secunda linea est ascriptus cursus media-

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229 summam] collocationem *C* 233 medius cursus] cursus medius *C* 235 ipsius] domini *C* 236 medio cursu] cursu medio *C* 237 in] *om. C* 240 et] *om. C* 241 dicat] *om. O* ‖ habet] habere *O* 243 secundum] *om. O* ‖ solis ortum] ortum solis *C* 246 omni] *om. C* 247 planetarum directa] directa planetarum *C* 248 sunt] facte *C* 248–249 faciunt anni] anni faciunt *C* 249 diei] *om. O* 250 imiteris] innieris(?) *O* ‖ et] *om. C* 251 scilicet … linea] si in prima linea est *C* 252 que] quam *C* 254 si] *om. O* 255 intrantis] intrans *O* ‖ que] qui *C* ‖ et] *om. O* 256 medius] mediatus *C* 257 anni initium] initium anni *C* 258 sui] et mensium *add. C* 259 et^{2}] *om. O* 260 differentia est] est differentia *C* ‖ annorum] anni *CO*

to the degrees and minutes you have received previously and subtract the whole sum from the mean motion at the beginning of January, which you have found previously by subtracting from the mean motion on 14 March the mean motion of the intervening days. And what is left after subtracting this from the mean motion at the beginning of January that is closest to the present time will be the mean motion at the beginning of the January that comes next after the nativity of our Lord Jesus Christ.

And since His nativity preceded January by 7 days, you will take the mean motion of this many days from the table for days. You will subtract it from the mean motion [at the beginning of] January. And your result will be the mean motion [corresponding to] the nativity of Christ at the beginning of the seven days that precede the beginning of January. And since the tables make the days and months begin from noon of the day [as counted by] the Christians and according to the common usage—such that whereas the common usage has the beginning of March at sunrise and says that the day begins at that time, according to the tables the day and month begins at the noon that comes after sunrise on the same day—, if the nativity was at the beginning of the day or year according to sunrise, one should subtract the motion in as many hours as there are from [sunrise to] noon from the motion at the same noon, and the result will be the motion that you seek at the Lord's nativity. By the same token, all [the other] mean motions will result without any error as long as you observe the rule that has been given. If you correct them, the result will be the true positions of the luminaries and planets at the same nativity.

Our tables, however, are [made] according to the tables of al-Ṣūfī. And they put the beginning of the year at March, namely, at the first noon of the day on which March begins according to the common usage. Imitate this in order to construct tables. And what you will find written next to the first number of the years of Christ, that is, in the first line of the table, is the mean motion of 1 March. This noon is the beginning of the day, month, and year according to the tables and the end of the preceding years, as if it were [expressly] written in the tables "when this many years of Christ are completed at noon at the beginning of March, which is the beginning of the following year, month, and day, the mean motion will be this many signs, degrees, minutes, [and] seconds, which are reckoned from the beginning of Aries." For just as March sets the beginning of the year and month according to these tables, so Aries is taken as the beginning of the signs. And those who make October the beginning of the year make Libra the beginning of the signs. And just as there is a difference of 20 years between the first line and the second one, what is written in the second line refers to the mean motion

us in principio Martii, scilicet in meridie, qui est post 20 annos completos ultra annos designatos in prima linea. Simile est in tertia linea et in sequentibus, quia in omnibus lineis sunt ascripti cursus mediati in initio Martii. Et est illa tabula annorum collectorum radix inventionis cursus mediati et fundamentum.

Et sicut in tabulis nostris ad imitationem tabularum Assophii est primus numerus annorum collectorum 1029 et sic fit progressio per superadditionem 20 annorum, sic et tu tabulas compositurus procedere poteris, incipiendo a | *O* 126$^{\mathrm{r}}$ quotlibet annis volueris et a cuius annis volueris superaddendo precedenti linee numerum annorum predictum, scilicet 20. Et incipere a quoto volueris anno, utpote a 1144 completis annis preteritis. Ab eodem presentem annum incipe a prima meridie Martii proximi preteriti. Et tunc oportet ipsi ascribere cursus mediatos in ea meridie. Deinde, ut efficas secundam lineam, superaddes 20 et fient 1164. Et ei ascribes cursus mediatos in illa meridie Martii qui fuerit post hos 20 superadditos, hoc observato ut semper vel a meridie vel a nocte media initium annorum, mensium, dierum facias, hac ratione quoniam inter meridies proximas vel medias noctes proximas est spatium 24 horarum equalium, quod inter ortus et occasus constat permutari.

⟨II.iv⟩

Qua vero arte tabulas annorum collectorum, expansorum, mensium, dierum, horarum, minutorum compones et dispones dicemus. Quoniam constat numerum annorum collectorum fieri ex annis expansis adunatis, anni vero ex mensibus, menses ex diebus, dies ex horis, horas ex minutis constare. A minutis erit initium compositionis, finis autem dispositionis. Et quoniam 60 minuta horam componunt, habito cursu mediato in tot minutis habetur et in una hora. Comperto et 24 horis constabit in die, quoniam 24 hore diem reddunt. Item dies 30 vel 31 vel 29 mensem componunt, quoniam non est equalis divisio, sicut in sequenti declarabitur. Et quoniam 12 menses annum faciunt cum horis aliquot, erit idem cursus in 12 mensibus qui fuerit et in

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261 qui] que *C* 267 1029] M.XXIII *O* 269 volueris] *om. C* 270 precedenti] sequenti *CO* 271 volueris anno] anno volueris *C* ‖ a] anno *O* 271–272 annis ... a] ante presentem annum. Incepit autem *C* 272–273 oportet] oportebat *C* 273 deinde] demum *C* 275 post] per *O* ‖ hoc] *om. O* 276 initium] in initio *C* ‖ annorum, mensium] mensium, annorum *C* 281 tabulas] tabularum *C* 282 minutorum] vel punctorum *add. s.l. O* ‖ compones et dispones] componas et disponas *C* 283 adunatis] coadunatis *C* 284 minutis] punctis sive minutis *O* 285 finis ... dispositionis] *om. O* 286 minuta] sive puncta *add. O* ‖ componunt] exprimunt *C* ‖ minutis] minuta *C* 287 et] *om. C* ‖ et] etiam in *C* 290 fuerit et] *om. C*

at the beginning of the March (i.e., at noon) after 20 years have been completed since the years indicated in the first line. The same principle applies to the third line and the following ones, because all lines contain the mean motion at the beginning of March. And this table of collected years is the root and basis for finding the mean motion.

And just as our tables imitate the tables of al-Ṣūfī by making the first number of collected years 1029 and proceed onwards by adding multiples of 20 years, so you can proceed yourself in order to construct tables, by starting from any number of years you wish and whatever [era] you like, [always] adding the aforementioned number of years to the previous line, namely, 20. And you [can] begin from any number of years you like, for instance from 1144 completed past years. From there, you must begin the present year from the first noon of the immediately preceding March. And one must then write next to it the mean motion at this noon. To produce the second line, you will then add 20 and they will become 1164. And you will write next to it the mean motion at the noon of March that comes after these 20 [years] have been added, bearing in mind that you always set the beginning of the years, months, [and] days at noon or midnight. The reason for this is that two adjacent noons or midnights are separated by a span of 24 equal hours, which [interval] is known to change between sunrises and sunsets.

II.iv

We shall [now] explain the method by which you will construct and arrange the tables of collected years, expanded [years], months, days, hours, [and] minutes. For it is understood that the number of collected years arises from the combined number of expanded years, but the years from [the combined number of] months, the months from days, the days from hours, the hours from minutes. Minutes will be the starting point for the construction, but are put last in the arrangement. And since 60 minutes make up one hour, once you have the mean motion in this many minutes, the [motion] in one hour has been obtained as well. Once one has ascertained [the motion] in 24 hours, one will also know [the motion] per day, seeing as 24 hours give back one day. Likewise, 30 or 31 or 29 days make up one month. For there is [here] no equal division, as will be made clear in what follows. And since 12 months make one year with a few hours, the motion in 12 months will be the same

anno. Item, quia 20 anni expansi unam collectionem annorum faciunt, 20 annorum habito cursu habebitur et unius collectionis. Erit itaque hic ordo servandus ut a minutis fiat initium.

Numeris adiacentibus duabus minutis horarum adicias tantundem et efficies cursum minutorum 4. Quare et ascribes IIII minutis hore cursum illum duplum, scilicet precedentis linee. Et secunde linee adicies primam ut habeas tertiam. Et semper precedenti adicias primam ut habeas sequentem. Et numerus minutorum hore sequens vincet precedentem duobus sic: 2, 4, 6, 8, 10, 12, et deinceps. Et singulis numeris in suis lineis ascribantur que eis adiacent. Sic etiam ut cum numerus tertiarum excreverit in 60 reducatur in ordinem secundarum et ibi una secunda scribatur pro 60 tertiis. Erit enim talis dispositio tabularum ut in primo ordine scribantur numeri minutorum hore sese binario superantium, ut iam diximus, donec perveniatur ad 60. Secundus ordo sit ordo signorum, tertius graduum, quartus minutorum, quintus secundorum, sextus tertiorum. Si itaque numerus tibi excreverit in 60 in ordine secundorum reducatur et si quid supra fuerit in suo dimittatur ordine. Sic de secundis minutum, de minutis gradum, de gradibus signum unum, si in tantum numerus potest excrescere. Sed quoniam nullus planetarum in minutis hore signum efficit vel etiam gradum, scribetur in ordinibus illis 0 significans scilicet "nihil habetur in signis vel gradibus." Et si minutam gradus non fecerint, scribatur 0 in ordine minutorum. Et designat tabula minutorum hore quantum percurrat planeta in una vel pluribus minutis hore secundum cursum mediatum, quantum scilicet percurrat circuli sui.

Et quoniam 60 minuta horam unam faciunt, debet sequi tabula horarum *C* 70^{v} hoc ordine disposita ut in primo ordine per | longitudinem scribatur numerus horarum usque ad complementum 24 in singulis lineis. Deinde sequitur ordo signorum et ordines gradus et minutorum, secundorum et tertiorum. Et in lineam hore unius ascribatur quod collectum fuerit 60 minutis hore in signum, gradibus, minutis, secundis, tertiis, quoniam id est cursus planetarum in 60 minutis hore et in hora. In linea horarum duarum scribatur duplum, in linea trium triplum prime linee, et deinceps per ordinem donec perveniatur ad complementum 24 horarum. Et latitudo in hac tabula et in predicta et sequentibus continebit ordines quotquot fuerint. Longitudo vero continebit crementa numerorum in singulis ordinibus.

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291 quia] *om. C* ‖ annorum] coniunctorum *add. C* 291–292 20 … et] habito cursu annorum 20 habitur cursus *C* 292 ordo] nobis *add. C* 293 fiat initium] incipiamus *C* ‖ *O*] 295 quare] quas *C* ‖ minutis] numeris *C* 302 tabularum] tabulis *C* 310 0] circulus *add. C* 311 0] circulus *add. C*

as that in one year. Likewise, since 20 expanded years make one collection of years, once one has obtained the motion in 20 years, one will also have obtained that in one collection. This, then, will be the order to follow, such that one starts from the minutes.

To the numbers adjacent to two minutes of the hour you must add the same amount and you will arrive at the motion in four minutes. You will accordingly write this doubled motion (i.e., of the previous line) next to four minutes. And you will add the first line to the second one to obtain the third one. And you must always add the first [line] to the preceding one to obtain the following one. And each following number of minutes of the hour will surpass the preceding one by two, viz. 2,4, 6, 8, 10, 12, and so on. And to each number in its line one must attribute what is adjacent to it, also [bearing in mind] that when the number of thirds grows to 60, it will be reduced to the column for seconds and one will write there one second for 60 thirds. For the tables will be arranged in such a way that in the first column one must write the number of minutes surpassing each other by steps of two, as we have already said, until they arrive at 60. The second column is the column for signs, the third for degrees, the fourth for minutes, the fifth for seconds, the sixth for thirds. And so, if your number grows to 60 it must be reduced to the column for seconds and if something is left it must be left behind in its column. In the same way, one minute [is made from] seconds, one degree from minutes, one sign from degrees, provided that such a high number can accrue. Yet since none of the planets accomplishes a sign in minutes of an hour, or even a degree, one will write in these columns "0," meaning "there are no signs or degrees." And if they do not accomplish a minute of a degree, one must write "0" in the column for minutes. And the table for minutes of an hour indicates the amount the planet traverses (i.e., how much of its circle it traverses) in one or several minutes of an hour according to its mean motion.

And since 60 minutes make one hour, the table that must come next is that for hours, which is arranged such that in the first column one writes, line by line, the number of hours up to 24. What comes next is the column for signs and the columns for degrees and minutes, seconds, and thirds. And in the line for one hour one must write what has been gathered in 60 minutes of an hour according to signs, degrees, minutes, seconds, [and] thirds, because it is the motion of the planets in 60 minutes of an hour as well as in one hour. In the line for two hours one must write twice this amount, in the line for three [one writes it] three times, and so on in sequence until one completes 24 hours. And the width of this table and the aforementioned one and of the following ones will contain a number of columns. And its length will contain the increments of the numbers in the individual columns.

Illud etiam notandum quod in compositionibus tabularum raro invenitur ordo tertiorum, quoniam minimam faciunt distantiam. Sed quoniam propter tertias omissas supra crementum secundorum additur in locis plerisque una secunda, tamquam proveniens ex omissis tertiis, ut etiam si omittantur in una vel duabus vel pluribus lineis una secunda tamquam ex eis collecta ascribatur quandoque, ne omnino omittatur crementum ex eis proveniens. Unde si plerumque inveniatur in tabulis numerus secundorum excrescere plus quam preceptio compositionis et ratio multiplicationis predicta exigat, ex tertiis omissis iudicandum est illud fieri crementum nec statim tabulam dampnare.

Quoniam vero 24 hore diem faciunt, habito quantum fiat in tot horis habitur simul quantum et die uno. Unde in compositione tabule dierum ascribetur per latitudinem uni diei quod totidem horis adiacebit. Et tertio loco sequitur tabula dierum quorum numerus crescit per longitudinem in 30, quoniam totidem mensem faciunt solarem. Et demonstrabit tabula ista dierum quantum Sol vel Luna vel planete perficunt in circulis suis die uno vel pluribus usque ad 30. Procedit vero crementum et in hac tabula sicut et in predictis, ut ad habendam secundam lineam dupletur prima, ad tertiam tripletur prima, ad quartam quadrupletur, et deinceps. Vel ad sequentem lineam faciendam addatur precedenti prima linea donec perveniatur ad 30.

Et quoniam non omnes menses eodem numero consistunt dierum, oportebit modis diversis numeros eorum efficere. Itaque ad habendum numeros adiacentes primo mensi, id est Martii, numeris adiacentibus 30 diebus adicies cursum diei unius, quoniam hoc mensis habet 31. Quod ergo collegeris in linea 30 in tabula dierum et in linea diei unius iunges et ascribes mensi Martii in tabula mensium. Que sic erit disposita ut primus ordo nomina mensium contineat et numerum in singulis lineis. Et primo mensi ascribitur, ut dictum est, ⟨cursus⟩ 31 dierum. Et ad faciendum numeros Aprilis, quia habet 30 dies, addes prime linee cursum 30 ⟨dierum⟩ in signis, gradibus, minutis, secundis et scribes in linea secunda. Et semper ad componendum numeros mensis constantis ex 30 diebus adicies linee precendeti cursum 30 dierum. Et ad componendum numeros mensis constantis ex 31 diebus addicies linee precedenti cursum 31 dierum. Et ad componendum numeros Februarii adicies precendeti linee cursum 28 dierum, quoniam hic mensis

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334 tabulam] tabula *C* 350 tabula] linea *C*

One should also note that in the constructions of tables one rarely finds a column for thirds, because they only account for a very small distance. Yet since, on account of the thirds that have been omitted, one adds in many places to the increment of seconds a second that arises from the omitted thirds, such that even if they are omitted, a second gathered from them will sometimes be ascribed in one or two or several lines, lest the increment that stems from them be entirely left aside. Accordingly, if one finds on many occasions that the number of seconds in the tables grows by more than what is demanded by the aforementioned rule of construction and principle of multiplication, one must deem this increment to arise from the omitted thirds and not condemn the table right away.

But since 24 hours make one day, once one has obtained the amount for this many hours, one will at the same time have obtained the amount for one day. In constructing the table for days, one will accordingly ascribe horizontally to one day what appears next to this many hours. And what follows in the third place is the table for days, whose number extends vertically to 30, because this [many] days make a solar month. And this table for days will demonstrate the amount of their circles the Sun and Moon and planets complete in one or several days up to 30. The increment in this table, however, grows in the same way as in the previous ones, such that to obtain the second line one doubles the first, triples it for the third, quadruples it for the fourth, and so on. Or, to make the following line, one adds the first line to the preceding one until one arrives at 30.

And since the months do not all consist of the same number of days, one will have to produce their numbers in different ways. And so, in order to obtain the numbers adjacent to the first month, that is, March, you will add the motion in one day to the numbers adjacent to 30 days, because this month has 31. You will, therefore, add together what you will have gathered from line 30 in the table of days and from the line for one day and ascribe [the sum] to the month of March in the table for months, which will be arranged such that the first column contains in each of its lines the names of the months as well as the number. And next to the first month one writes the motion in 31 days, as has been said. And in order to produce the numbers for April, which has 30 days, you will add to the first line the motion in 30 days according to signs, degrees, minutes, [and] seconds, and you will write [the result] in the second line. And to compose the numbers of a month consisting of 30 days, you will always add to the preceding line the motion in 30 days. And to compose the numbers of a month consisting of 31 days, you will add to the preceding line the motion in 31 days. And to compose the numbers of February, you will add to the preceding line the motion in

ex tot diebus constat. Et demonstrat hec tabula quantum perficiant planete in circulis suis in uno mense vel pluribus usque ad 12.

Composita itaque tabula mensium sequitur tabula annorum expansorum. Et quoniam menses 12 unum annum faciunt cum additione aliquot horarum, sequitur ut habito cursu in mensibus 12 habitur et cursus in anno uno, horis omissis. Unde in tabula annorum radicem pones numerum adiacentem 12 mensibus, qui scribitur in linea mensis Februarii. Et numerum illum uni anno ascribes in prima 〈linea〉 omisso cursu horarum que sunt ad anni complementum. Nec continebit linea prima nisi cursum 365 dierum, omissis horis predictis. Sed si fuerit bissextus in anno primo illo, scilicet in quo tabulas compones, adicies cursui mensium 12 cursum diei unius et scribes in prima linea. Et quoniam quisque annus quartus bissextilis est ad lineam precedentem adicies cursum diei unius et ascribes anno bissextili.

Tabule autem nostre, composite scilicet anno Christi 1143, habent secundum annum bissextilem. Et invenies in eis in tabula annorum expansorum conscriptum secundo anno numerum precedentis anni duplatum et cursum diei unius. Similiter in 6, in 10, in 14, in quo invenies superadditum cursum unius diei. Sic ergo erit tabula ista composita ut primo anno ascribatur cursus mensium 〈12〉, secundo duplum, tertio triplum, et deinceps. Vel semper precedenti linee adicies primam ut habeas sequentem donec ad 20 annos perveniatur. Et preterea secundum quod evenerit bissextus secundum morem Christianorum semper in anno bissextili adicies cum additione precedenti cursum diei unius. Designabit itaque tabula annorum quantum perficiat planeta circuli sui in anno uno vel pluribus usque ad 20. Et quod in annis 〈non〉 bissextilibus minus debito propter horarum omissionem ascribitur in bissextilibus per additionem cursus diei unius recompensatur.

Hoc itaque modo complebuntur tabule minutorum, horarum, dierum, mensium, annorum expansorum. Et erit radix ominum a minutis horarum, que si veraciter sumpta fuerit et ratio compositionis tabularum ordine predicto processerit sine omni defectu cursum mediatum Solis et Lune et planetarum, scilicet in circulis suis, invenies. Queque autem tabula suam habet radicem. Utpote tabula minutorum hore radicem que adiacet uni minuto

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376 14] 914 *C* 377–378 ascribatur] scribatur *C* 381 morem] minorem *C* ‖ adicies] adiciat *C*

28 days, because this month consists of this many days. And what this table shows is the amount of their circles that the planets complete in one month or several up to 12.

Having constructed in this fashion the table for months, what comes next is the table for expanded years. And since 12 months make one year with the addition of a few hours, it follows that once one has obtained the motion in 12 months, one has also obtained the motion in one year, with hours omitted. You will accordingly use the number adjacent to 12 months, which is written in the line for the month of February, as the root for the table of years. And you will write this number next to one year in the first line while disregarding the motion in the hours that are left until the end of the year. And the first line will contain no more than the motion in 365 days, while the aforementioned hours are omitted. But if there is a bissextile day in this first year (i.e., the [year] in which you will compose the tables), you will add the motion in one day to the motion in 12 months and write [the result] in the first line. And since every fourth year is bissextile, you will add to the preceding line the motion in one day and ascribe [the result] to the bissextile year.

But our tables, which were constructed in the year of Christ 1143, have a bissextile day in the second year. And you will find that the number that is written in their table for expanded years for the second year is the double the number of the preceding year plus the motion in one day. The same applies to the 6th, the 10th, and the 14th, in which you will find that the motion in one day has been added. This table will be constructed in such a way that the motion in 12 months is written next to the first year, twice this amount next to the second, three times this amount next to the third, and so on. Or, you will always add the first line to the preceding line to obtain the following one, until one arrives at 20 years. And furthermore, whenever the bissextile day arises according to the manner of the Christian, you will always in a bissextile year add the motion of one day together with the preceding addition. And so, the table for years will show the amount of its circle that a planet traverses in one year or in several up to 20. And what is missing from the due amount in non-bissextile years owing to the omission of hours is compensated for in bissextile ones through the addition of the motion in one day.

This is the manner, then, in which the tables for minutes, hours, days, months, [and] expanded years will be completed. And the root for them all will come from the minutes of the hour. If this [root] is taken correctly and the method of constructing the tables proceeds in the aforementioned sequence, you will find the mean motion of the Sun and Moon and planets without any error. Each table, however, has its root. The table for minutes of the hour, for instance, has as its root the amount adjacent to one minute,

vel duobus, que duplanda est vel triplanda vel aliis numeris multiplicanda ad habendum quod convenit 60 minutis que sunt una hora. Radix autem tabule horarum ⟨est quod adiacet prime hore, tabule dierum est quod adiacet primo diei, tabule mensium⟩ est quod adiacet primo mensi vel 30 diebus et tabule annorum quod adiacet uni anno vel mensibus 12, horis omissis.

Et si integre cursum anni unius habere volueris, sumes quod adiacet in linea prima annorum, qui est cursus 365 dierum, et quod adiacet 6 horis, que scilicet desunt ad complementum unius anni. Que simul iuncta faciunt cursum unius anni in signis, gradibus, minutis, secundis. Habita vero radice unius anni, quanta scilicet ascribitur 365 diebus, inde invenies cursum 20 annorum sic. Duces numerum secundorum in 20 et partieris super 60 et *C* 71ʳ facies minutas. Si que | superfuerint erunt secunda. Similiter minuta in 20 duces et partieris in 60 et facies gradus. Que remanserint erunt minuta. Gradus similiter convertes in signa et si multiplicatio vel aggregatio fecerit signorum circulum, id est 360 gradus, vel signa 12, illud eicies. Sumes reliquum. Signa similiter multiplicabis et eicies circulum, si evenerit, et reliquum sumes. Et quoniam annus in tabulis ⟨est⟩ sine quarta, adicies ei quod collegeris cursum 5 dierum, quoniam tot dies colliguntur in 20 annis ex quartis. Et totum quod provenerit erit cursus in 20 annis eiectis circulis. Exemplum in tabula: cursus medius Draconis 40 secunda, 19 gradus et nihil in signis, nihil in minuta ⟨…⟩ in annis 20.

Restat tabula annorum coniunctorum, que sic componitur. Radicem oportet prius constitui, que talis erit. Sumendum est principum anni a mense aliquo, utpote a Martio, qui sit et initium anni et initium mensium. Et considerandum est in quot signis, gradibus, minutis, secundis sint planete in meridie prime diei illius mensis, ut meridies illa statuatur principium anni, mensis, diei. Et hic locus planetarum inventus erit radix. Et designetur annus secundum annos Christi vel Alexandri vel alicuius rei notabilis, ut scilicet intelligatur quotus annus fuerit Christi vel Alexandri cuius locus planetarum talis fuerit in illa meridie. Et illi numero annorum ascribatur radix inventa. Deinde ordo ille annorum crescit per vicenos et quantum volueris produ-

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409 5] 7 *C* 417 meridie] prima *add. C* 418 annus] dies *C*

or two, which must be doubled or tripled or multiplied by other numbers to obtain the amount that goes with 60 minutes, which are one hour. The root of the table for hours, however, is that which is adjacent to the first hour. [The root of] the table for days is that which is adjacent to the first day. [The root of] the table of months is that which is adjacent to the first month or 30 days and [the root of] the table of years is that which is adjacent to one year or 12 months, with hours omitted.

And if you wish to have the complete annual motion, you will take what is adjacent to the first line of the years, which is the motion in 365 days, and what is adjacent to 6 hours, which are what is left until one year is complete. Joined together, these make the motion in one year according to signs, degrees, minutes, [and] seconds. Once you have obtained the root of one year, namely, the amount written next to 365 days, you will find from it the motion in 20 years in the following way. You will multiply the number of seconds by 20 and divide by 60 and you will make minutes. If something remains, they will be seconds. You will in the same way multiply the minutes by 20 and divide by 60 and you will make degrees. What remains will be minutes. You will in the same way convert the degrees into signs and if the multiplication or addition makes a whole circle of signs (i.e., 360°) or 12 signs, you will cast this out. You will take the remainder. You will in the same way multiply the signs and cast out the [whole] circle, if it arises, and take the remainder. And since the year in the table is without the quarter-day, you will add to the sum the motion in 5 days, because this is how many days are gathered from the quarter-day in 20 years. And the resulting total will be the motion in 20 years after [any whole] circles have been cast out. An example from the table: the mean motion of the Dragon [is] 40 seconds, 19 degrees, no signs, no minutes ⟨…⟩ in 20 years.

What is left is the table for collected years, which is constructed in the following way. First, one must establish the root, which is of the following kind. One must start the year from some month, such as March, which is the beginning of the year and the beginning of the months. And one must consider the number of signs, degrees, minutes, [and] seconds [that mark the positions] of the planets at noon of the first day of this month, so that this noon is established as the beginning of the year, month, [and] day. And the position of the planets thus found will be the root. And the year will be marked according to the era of Christ or Alexander or according to some other notable event, so that one can know the number of the years of Christ or Alexander in which the position of the planets was like this at the noon in question. And the root that has been found will be ascribed to this number of years. This column of years will afterwards increase by multiples of 20 and

cere. Tamquam si in prima linea scriberetur numerus annorum Christi 1029 et deinde numeri designantes in quot signa vel gradus et minuta et secundis esset Sol prima meridie Martii, verbi gratia 11 signa, 14 gradus, 30 minuta, 20 secunda, tamquam si scriberetur “annis Christi 1029 completis Sol erat remotus a capite Arietis per signa 11, gradus 14 et minuta 30 et secunda 20.” Similiter de Luna et planetis faciendum est et de cursu Draconis. Erit itaque radix in cursibus mediis ominum planetarum cui ad faciendam secundam lineam addendus est cursus annorum 20. Et semper quotiens volueris adicies precedenti linee cursum annorum 20 ad faciendam lineam sequentem, quoad producere volueris tabulam. Tabule autem partium designent per annos coniunctos quantum distent planete a locis altis epicyclorum in numero annorum Christi prescriptorum et per primam lineam quantum distent prima meridie mensis Martii. Potest etiam initium sumi ab aliis mensibus, utpote Ianuarius, Februarius.

for as much as you wish to stretch out [the table]. So if one were to write in the first line the number 1029 of the years of Christ and afterwards the numbers showing in which signs or degrees and minutes and seconds the Sun was located at the first noon of March, for example 11s 14;30,20°, this would be tantamount to writing "when 1029 years of Christ were completed the Sun was removed from the head of Aries by 11 signs, 14 degrees, 30 minutes, and 20 seconds." The same must be done for the Moon and the planets and the motion of the Dragon. And [the result] will be the root for the mean motions of all planets, to which the motion in 20 years must be added to make the second line. And you will always add the motion in 20 years to the preceding line, as many times as you wish, in order to make the following lines, for as long as you wish to stretch out the table. The tables for the [mean] anomalies, however, indicate with their collected years by how much the planets are removed from the apogees of the epicycles in the number of years of Christ written before them, and with the first line [they indicate] by how much they are removed at the first noon of March. The beginning can also be taken from other months, such as January, February.

III ⟨De motibus planetarum⟩

⟨III.i⟩

O 126^{r} Cursus mediatus Solis et Lune et planetarum est quem perficiunt in circulis suis. Cursus directus est quantum perficiunt de circulo firmamenti. Equaliter vero semper perficiunt in circulis suis, inequaliter de circulo firmamenti. Et sicut circulus firmamenti est divisus in 12 partes equales, sicut et circuli planetarum. De Sole vero prius dicendum est, secundum quod constabit de aliis.

Sol perficit temporibus equalibus 12 partes circuli sui. Inequaliter vero perficit partes equales firmamenti. Paucioribus enim diebus perficit 6 signa a Libra ad Aries quam 6 signa ab Ariete ad Libram. Quod inde est quia centrum terre, quod est centrum firmamenti, non est centrum circuli Solis. Sed mutatur centrum circuli Solis ab illo duobus fere gradibus. Unde provenit Solem esse elevatiorem a terra in alia parte circuli, in alia propinquiorem. *O* 126^{v} | Locus erit vero in quo maxime elevatus. Dicitur locus eius altus vel ‘augis’ ipsius. Locus in quo est proximus terre dicitur locus eius imus vel ‘nadir’, id est oppositum augis. Et quoniam quandoque in circulo suo est in alio gradu, in alio vero gradu firmamenti, quod contingit ex predicta mutatione centrorum, quandoque vero in eisdem gradibus circuli sui et firmamenti, non statim cognito cursu et loco suo in circulo suo scitur locus eius in circulo firmamenti, cum in eisdem semper non sit gradibus.

Cursus autem mediatus per tabulas invenitur. Locus autem directus per easdem non potest inveniri. Unde oportuit artem invenire et tabulas componere per quas dato prius cursu mediato possit inveniri locus directus, id est locus ipsius in gradibus firmamenti. Et deprehensum est Solem, cum est in loco alto suo vel imo, esse in eodem gradu circuli sui et firmamenti. Postea vero inde ascendens vel descendens fit in diversis et pluribus gradibus quandoque circuli sui quam firmamenti, quandoque in paucioribus. In loco alto vel imo solummodo adequari. Proinde inveniendus est primum

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3 [*O* ‖ quem] que *C* 4 circulo firmamenti] firmamento *C* 5 semper] *om. C* 6 est divisus] divisus est *C* ‖ sicut] *om. C* 7 dicendum] predictum *O* ‖ est] *om. C* ‖ de] iam in *O* 11 quia] quod *C* 15 erit … quo] vero in quo est *C* ‖ locus … eius] locus altus eius *C* 16 eius imus] imus eius *C* 17 oppositum] oppositio *C* ‖ quandoque] sol *add. C* 18 gradu] *om. C* 20 et loco suo] suo et loco *C* ‖ circulo] *om. O* 20–21 circulo firmamenti] firmamento *C* 21 semper] *om. O* 22 per … autem] et *C* 23 easdem] tabulas *add. C* ‖ et] in *C* 23–24 componere] componi *C* 24 prius] primum *O* ‖ cursu … possit] medio cursu posset *C* 24–25 id est] scilicet *C* 25–26 cum est] esse *C* 26 esse] *om. C* ‖ circuli sui] sui circuli *C* 27 ascendens … descendens] discedens vel accedens *C* 28 circuli sui] sui circuli *C* 29 loco alto] alto vero loco *C* ‖ inveniendus] minuendus *C*

III On the Motions of the Planets

III.i

The mean motion of the Sun and Moon and the planets is the one they complete with respect to their own circles. The true motion is what they complete with respect to the circle of the firmament. They always move equally on their own circles, but unequally with respect to the circle of the firmament. And just as the circle of the firmament is divided into 12 equal parts, so are the circles of the planets. The Sun shall be addressed first and [what will be said about it] will be true of the others.

The Sun completes the 12 parts of its own circle in equal amounts of time. By contrast, it [takes] unequal [amounts] to complete equal parts of the firmament. For it takes fewer days to complete the 6 signs from Libra to Aries than the 6 signs from Aries to Libra. This stems from the fact that the centre of the Earth, which is the centre of the firmament, is not the centre of the circle of the Sun. Instead, the centre of the circle of the Sun is about two degrees removed from it. It consequently happens that the Sun is farther from the Earth in one part of its circle and nearer in the other. But there will be a place where it is at its greatest distance. It is called its apogee or 'aux'. The place where it is nearest to the Earth is called its perigee or 'nadir', which is the part opposite the aux. And since it is sometimes [found] in one degree on its own circle but in another degree on the firmament, which happens as a result of the aforementioned eccentricity, but sometimes in the same degrees on its own circle and the firmament, knowing its motion and position on its own circle does not immediately lead to knowledge of its position on the circle of the firmament, seeing as it is not always located in the same degrees.

The mean motion is found by means of tables; yet the true position cannot be found from the same [tables]. It was therefore necessary to invent a method and construct tables that make it possible to find the true position, that is, its position among the degrees of the firmament, given prior [knowledge of] the mean motion. And it has been discovered that the Sun, when it is at at apogee or perigee, is in the same degree on its own circle and on the firmament. But afterwards, as it ascends or descends, it appears in different [degrees], and sometimes in a greater number of degrees on its own circle than on the firmament, sometimes in a smaller one. Only at the apogee and perigee do they become equal. One must accordingly first find the

cursus medius et locus Solis in circulo suo et postmodum inquiratur in gradu firmamenti. Appellatur autem directio Solis adequatio circuli gradus cum gradu firmamenti. Cuius scilicet directio est ac si linea protensa esset a gradu circuli ad gradum firmamenti quem ex directo aspicit. Que quidem est, ut diximus, in loco alto vel imo in eodem gradu utriusque. Quia cum Sol est in alto loco est in 27 gradu Geminorum in utroque circulo. Inde discedens versus locum imum statim in gradu circuli sui preterit eundem gradum eundem firmamenti et adeo preterit ut, cum Sol pervenerit ad 27 gradum Virginis et ad caput Libre in circulo suo, sit posterior duobus fere gradibus in circulo firmamenti. Proinde figuram subiciemus, ut in ea pateat qualiter pretereat in circulo suo gradum eundem firmamenti, vel pretereatur ab eodem.

Sit circulus firmamenti divisus in 12 partes et cuique parti ascribatur littera una alphabeti per ordinem incipiens ab 27 gradu Geminorum, in quo est locus altus Solis. Et circulus Solis qui est interior similiter dividatur et distinguatur per easdem litteras, facto initio in loco alto, scilicet 27 gradu Geminorum. Hee autem sunt littere: ABCDEFGHIKLM. Erit itaque in A altus *O* 127^{r} locus et G locus imus. Et in D erit quadratum ab alto in imum et in K | quadratum ab imo in altum oppositum alteri quadrato, scilicet D. Igitur Sol in circulo suo equali spatio temporis perficit omnes quadratos, scilicet ab A ad D et sic ad G, deinde ad K. Non sic equaliter perficit equales partes firmamenti. Nam cum pervenit in circulo suo ab A ad D nondum pervenit ad D in firmamento, sed duo fere gradus interiacent ad quos percurrendos antequam perveniat ad D duos fere dies consumet. Unde Sol videtur tardior in illa quarta. Cum itaque sit Sol in D sui circuli est in alio gradu firmamenti distanti a D, qui sit N. Tunc igitur Sol erit in N gradu firmamenti et gradus N *C* 71^{v} est in directo gradus D in | circulo Solis. Invento igitur Sole in D circuli sui non est in D firmamenti, sed potius in N.

Inde descendens ad aliam quartam, scilicet locum imum, id est G, illam partem firmamenti citius priori perficit, adeo ut simul perveniat at utrum-

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30 cursus medius] cursus medius *C* ‖ inquiratur] *om. C* 31 circuli … cum] gradus circuli in *C* 32 firmamenti] in *add. C* 35 est … Geminorum] in 17 gradu Geminorum est *C* ‖ 27] 17 *C* 36 gradum eundem] eundem gradum *C* 37 sol] preterit et *O* ‖ et] vel *C* 38 duobus fere] fere duobus *C* 39 proinde … subiciemus] propter quod subicienda figura *O* ‖ pretereat] preterierit *O* 40 gradum … firmamenti] gradus firmamenti eiusdem *O* ‖ eodem] eis *O* 44 in] a *C* 45–46 altus locus] locus altus *C* 46 G … imus] in Geminis locus imus in G *C* 47 in^{1}] ad *C* 48 quadratos] quartas *C* 49 G] et *add. C* ‖ equales partes] partes equales *C* 54 erit] etiam *O* 57 descendens] discedens *C* 58 partem] quartam *C*

mean motion and the position of the Sun on its own circle and afterwards search for the degree on the firmament. The 'correction' [*directio*] of the Sun, however, is the name for the process of making a degree on [its own] circle equal with a degree on the firmament. This correction works as if one were to draw a line from the degree on the circle to the degree on the firmament that directly faces it. At the apogee or perigee, [this line] is in the same degree of either [circle], as we have said. For when the Sun is at the apogee it is in the 27th degree of Gemini of either circle. As it then departs towards the perigee it immediately anticipates with a degree on its own circle the same degree on the firmament and anticipates it to such an extant that when the Sun has arrived at the 27th degree of Virgo and at the head of Libra of its own circle, it is about two degrees behind on the circle of the firmament. We shall accordingly subjoin a diagram, so that it may elucidate the way [the Sun] anticipates in its own circle the same degree on the firmament or is anticipated by it.[1]

Let the circle of the firmament be divided into 12 parts and assign to each part one letter in alphabetic order, beginning from the 27th degree of Gemini, which is where the Sun's apogee is located. And the circle of the Sun, which is inside it, should also be divided and marked with the same letters, beginning from the apogee (i.e., the 27th degree of Gemini). The letters are these: ABCDEFGHIKLM. The apogee will accordingly be at A, the perigee at G. And D will be the point of quadrature from apogee to perigee and K the point of quadrature from perigee to apogee that lies opposite the other point, namely, D. The Sun completes all quarters of its own circle (i.e., from A to D and onwards to G, afterwards to K) in an equal time span. It will not complete equal parts of the firmament in this equal manner. For upon having gone from A to D on its own circle it has not yet reached D on the firmament, but there is a gap of about two degrees that it will take about two days to traverse before reaching D. As a result, the Sun will be perceived to be slower in this quarter. Once the Sun is at D on its own circle, it is accordingly at a different degree on the firmament, one removed from D, which let be N. The Sun will then be at degree N on the firmament and degree N is opposite degree D on the Sun's own circle. It follows that when the Sun is found at D on its own circle, it is not at D on the firmament, but rather at N.

When it afterwards descends to the other quarter, that is, towards the perigee (i.e., G), it completes this part of the firmament more quickly than the previous one, so much so that it arrives simultaneously at either G. And

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[1] See Figure 1 on p. 158.

que G. Et in quantum prius videbatur tardando in priori quarta amisisse, in hac videtur quarta accelerando recuperasse. Et iterum in G adequantur et tunc in eodem gradu firmamenti est et sui circuli. Deinde procedens versus locum altum precedit gradum sui circuli in gradu firmamenti, adeo ut cum pervenerit ad K firmamenti longe distat a K in suo circulo per duos fere gradus et cursum fere duorum dierum et sit in O gradu circuli sui et tanto prius sit in gradu firmamenti quam in eodem gradu sui circuli quanto superius prius pervenit ad gradum sui circuli, scilicet D, quam ad eundem gradum firmamenti. Et eadem fit proportio accedendo ab imo ad altum et in recedendo ab alto ad imum. Et eadem proportione vincitur a gradu firmamenti in gradu circuli sui qua proportione vincat gradum firmamenti in gradu suo. Unde secundum easdem proportiones erunt directiones eiusdem celeritatis in hac quarta et in proxima precedenti. Sed quantum hic videtur accelerando acquisisse tantum in ultima quarta tardando in eadem proportione quam et prius accelerando amittet. Ut cum pervenerit ad locum altum, scilicet A, sit in eodem gradu et firmamenti et circuli sui. Quapropter initium directionis est a loco alto, secundum quem due distinguntur partes Solis, una ab alto ad imum, altera ab imo ad altum, ut ab A ad G et a G ad A. Et sunt VI signa hinc et VI illinc per numerum graduum inchoata a 27 gradu Geminorum et inde ad 27 Cancri et deinceps. Initium supputationis cursus medii ab Ariete.

Sic ad habendam directionem scire oportet in qua parte sit Sol, id est an sit in VI signis ab alto ad imum an ab imo ad altum. Et ideo inquirendum est quantum distet Sol a loco alto. Quoniam si distet per unum gradum vel per duos vel per signa duo vel tria et usque ad VI aliter directio facienda est *O* 127$^{\mathrm{v}}$ | quam si fuerit supra VI signa. Quoniam si est in loco alto ad imum, crescit numerus graduum sui circuli a gradibus circuli firmamenti. Minuendus est a gradibus vel minutis circuli sui ut fiat equatio ad gradum vel minutum firmamenti, quia cursus maior est secundum circulum suum quam secundum circulum firmamenti. Et inquirendum est sic quot gradus desint in

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59 tardando] tardare et *O* 60 quarta] *om. C* 61 deinde] inde *add. C* 64 et] id est per *C* ‖ fere … dierum] duorum dierum fere *C* ‖ gradu] *om. C* ‖ et] sed *O* 65 tanto] tantum *C*; tamen *O* ‖ in gradu] *gem. O* 65–66 circuli … sui] *om. per. hom. O* 69 proportione vincat] vincat superius *C* 70 easdem … erunt] eandem proportionem erunt eedem *C* ‖ eiusdem] vero *add. C* 71 celeritatis] est *add. C* 72 tantum] *om. C* ‖ in] *om. C* 74 sit] itidem *add. C* 75 una] est *add. C* 77 inchoata] supputatione *add. C* 78 cursus] *om. O* 80 sic] igitur *C* 81 VI] sex *O* 81–82 inquirendum est] requirendum *C* 82 distet sol] sol distet *C* ‖ distet] distat *C* 84 fuerit] sit *C* 84–85 ad … crescit] crescit ad imum *C* 86 gradibus … minutis] gradu *C* ‖ sui] *om. O* ‖ vel minutum] *om. C* 87 cursus … est] minor est cursus *C*; cursus minor est *O* 88 circulum firmamenti] firmamentum *C* ‖ in] *om. C*

the amount that it appeared to have lost in the previous quarter by slowing down, it appears to have regained in this quarter by accelerating. And they become equal again at G and then [the Sun] is at same degree on the firmament and its own circle. Afterwards, as it moves towards the apogee, it anticipates the degree on its own circle with the degree on the firmament, so much so that when it has arrived at K on the firmament it is far removed from K on its own circle, by roughly two degrees and the motion of about two days, and it is at O on its own circle and has arrived at the degree on the firmament sooner than at the same degree on its own circle by as much as it previously had arrived at the degree of its own circle (i.e., D) sooner than at the same degree of the firmament. And its ascent from perigee to apogee and return from perigee to apogee both happen at the same proportion. And the proportion by which the degree on its own circle is surpassed by the degree on the firmament is the same as that by which it surpasses the degree on the firmament with its own degree. The corrections that correspond to the same velocity in this quarter and the immediately preceding one will accordingly be according to the same proportions. Yet the amount that [the Sun] here appears to acquire by accelerating is the same as what it loses in the final quarter by slowing down by the same proportion as before when accelerating, such that, when it has arrived at the apogee (i.e., at A), it is in the same degree on the firmament and on its own circle. The correction hence begins at the apogee, according to which one distinguishes two parts of the Sun, one from apogee to perigee, the other from perigee to apogee, that is, from A to G and from G to A. And there are 6 signs on either side, with the number of degrees beginning from the 27th degree of Gemini and then from the 27th [degree of] Cancer, and so on. The calculation of the mean motion begins from Aries.

In order to obtain the correction, one must therefore know the part in which the Sun is located, that is, whether it is in the 6 signs from apogee to perigee or [in those] from perigee to apogee. And to this end one must seek the Sun's distance from the apogee. For if its distance is one degree or two, or two or three signs up to 6, the correction must be made differently than if it is greater than 6 signs. For if it is between apogee and perigee, the number of degrees on its own circle increases with respect to the degrees on the circle of the firmament. A subtraction must [therefore] be made from the degrees or minutes on its own circle to make them equal with degrees and minutes on the firmament, because its motion according to its own circle is greater than according to the circle of the firmament. And one must examine in this manner the number of degrees that are missing from the number

numero firmamenti ad complementum graduum circuli sui in quibus est. Si vero fuerit ultra VI signa remotus a loco alto et fuerit ab imo ad altum, quoniam numerus graduum sui circuli in quibus est vincitur a numero graduum vel minutorum firmamenti, addenda est directio ad gradus circuli ut inde habeatur locus directus in firmamento.

Quanta porro directio ad unum gradus pertineat, quanta ad plures, in tabulis directionis ascribitur. Quia numero graduum vel signorum ascribitur sua directio que addenda est cursui mediato vel minuenda secundum datam regulam inventa parte. Maxima autem directio est in quadratis locis alti et imi. Quantitas autem directionis et qualiter inequaliter crescat vel decrescat per rationem arcus et corde investigata est, sicut et augmentum horarum. Invenies vero quantum distet Sol a loco alto minuendo locum altum, cuius supputatio est ab Ariete, a cursu mediato, cuius similiter supputatio ab Ariete.

Sit Solis cursus mediatus 3 signa ab Ariete et quatuor gradus. Qui erit in quatuor gradibus Cancri. Locus vero altus est in duobus signis et 27 gradibus supputatis ab Ariete. Erit itaque in 27 gradu Geminorum. Minuantur itaque hec a predictis. Remanebunt 7 gradus a loco alto distans. Et est in parte ab alto ad imum. Constat ergo minuendam directionem esse. Quam requires in linea graduum 7, quot scilicet remanserunt post minutionem loci alti a cursu medio. Quod si Solis cursus medius fuerit in duobus signis ab Ariete addendus est numerus signorum 12. Et erunt 14 a quibus minues locum altum. Remanent 11 signa et 3 gradus. Que si supputentur a 27 gradu Geminorum invenies 30 gradus Tauri, quia a 27 gradus Gemini sunt 11 signa et 3 gradus ad ultimum gradum Tauri. Vel, cum fuerit Sol in paucioribus signis vel gradibus quam locus altus, minues cursum mediatum a loco alto. Et idem proveniet.

Quoniam vero compertum est gradus equaliter distantes hinc ⟨et⟩ illinc a loco alto equalem habere directionem, illis in eadem linea positis equa directio ascribitur. Gradus enim sequens locum altum et gradus precedens equaliter ab eo distant, sic et gradus secundi, sic gradus tertii, et deinceps. Et tantum distat ab eo gradus sequens quantum 11 signa et 29 gradus, et duo gradus equaliter 11 signis et 28 gradus, et deinceps. Item tantum distat unum

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90 vero] *om. C* 91 vincitur … numero] vacitur minor *C* 92 vel minutorum] *om. C* 95 ascribitur] describitur *C* 97 inventa] in *add. C* ‖ directio] habenda *add. O* ‖ in] *om. C* ‖ locis] loci *O* 98 qualiter] quare *C* 100 distet sol] sol distet *C* 101 est] *om. O* ‖ cuius] qui *C* ‖ supputatio] supputatur *C* 103 cursus mediatus] mediatus cursus *C* 105–106 itaque hec] ergo hoc *C* 107 directionem esse] esse directionem *C* 108 graduum 7] 7 gradus *C* 108–109 a cursu medio] ad cursum medium *C* 111 a] ab *C* 112 30] vel tricesimus *add. O* 112–113 quia … Tauri] *om. per. hom. O* 114 altus] *om. C* 115 quoniam] quando *O* ‖ vero] ratione *add. C* 119 et^1] *om. O*

[of degrees] on the firmament to complete the [number of] degrees that are its location on its own circle. If, on the other hand, it is more than 6 signs removed from the apogee and is located between perigee and apogee, one must add the correction to the degrees on [its own] circle to thereby obtain the true position on the firmament, seeing as the number of degrees that are its location on its own circle is surpassed by the number of degrees or minutes on the firmament.

The tables of correction show the amount of the correction that pertains to one [or] to several degrees. For each number of degrees or signs has written next to it its correction, which must be added to the mean motion or subtracted according to the rule just given depending on the part [of the circle] that has been found. The largest correction, however, is [found] at the points of quadrature from the apogee and perigee. But the amount of the correction and the manner in which it increases and decreases unequally has been found out via the method of arc and chord, as with the growth of hour[-lengths]. As for the distance of the Sun from the apogee, you will find it by subtracting the apogee, which is reckoned from Aries, from the mean motion, which is likewise reckoned from Aries.

Let the mean motion of the Sun be 3s 4° from Aries, so that it will be at 4° Cancer. The apogee, however, is at 2s 27° reckoned from Aries, so that it will be at 27° Gemini. These [2s 27°] will consequently be subtracted from the aforementioned [3s 4°]. What will be left is a distance of 7° from the apogee. And [the Sun] is in the part from apogee to perigee. It is therefore evident that the correction must be subtracted. You will seek it in the line for 7°, which is the amount that was left after subtracting the apogee from the mean motion. But in a case where the Sun's mean motion is two signs from Aries, one must add 12 signs. And there will be 14, from which you will subtract the apogee. What remains are 11s 3°. If these are reckoned from 27° Gemini, you will find 30° Taurus, because 27° Gemini are 11s 3° from the final degree of Taurus. Alternatively, if the Sun occupies fewer signs or degrees than the apogee, you will [simply] subtract the mean motion from the apogee, and the result will be the same.

But since it has been ascertained that degrees that are at equal distance on either side of the apogee have the same correction, they are placed in the same line [in the table and] the same correction is ascribed to them. For the degree that follows the apogee and the degree that precedes it are at equal distance from it, as is also true of the second degrees, the third degrees, and so on. And the degree that follows it has the same distance as 11s 29°, and 2° have the same [distance] as 11s 28°, and so on. Likewise, one sign following

signum sequens et 11 sequentia. Similiter 2 et 10, sic 3 et 9, sic 4 et 8, sic 5 et 7, sic 6 hinc, 6 illinc. Et ideo ipsis equales ascribuntur directiones. Quas hinc minuas, illinc addas, secundum predictam regulam.

⟨III.ii⟩

O 128^r Luna habet circulum proprium, sicut et Sol, in quo facit cursum mediatum. Cuius centrum remotum est a centro firmamenti per 5 gradus. Cursus vero mediatus eius in tabula secundum artem traditam invenitur sicut et Solis. Per quam tabulam deprehenditur in quo gradu sive minuto sit illius circuli. Quo invento oportet requirere in quo gradu sit secundum firmamentum. Que inventio utilis est ad opera tam astrologie quam astronomie. Parum enim refert in quo gradu sit circuli proprii cognoscere, nisi invenerimus in quo gradu sit secundum circulum firmamenti. Que quidem inventio eo difficilior est secundum Ptolomeum quod cum circulo suo maiore, in quo facit cursum suum medium, habet circulum parvum illi innexum et habentem punctum suum in illo. Unde maxima generatur difficultas inquirendo locum suum directum cum secundum diversos circulos habeat plures motus diversitates. Per circulum enim maiorem fertur ab occidente in orientem, in circulo minori econtra. Nihilominus tamen in maiori circulo quodammodo minor circumfertur ad complementum circuitus sui.

Ad cuius rei evidentiam figuram oculis subicimus. Et circulum maiorem in octo partes divisum octo litteris designavimus positis ordine retrogrado, sicut et circulus ille contra orientem ab occidente fertur: NMLKIHGF. Circulum vero brevem quadripartitum quatuor litteris | *C* 72^r distinximus ordinatim positis, scilicet ABCD. Et punctum E et punctum maioris O. Fertur autem Luna in circulo brevi ab A ad B, sic ad C, deinde ad D, et sic revertitur ad A. In maiori vero circulo fertur ab N in M, sic in L et K et I, deinde ad H, sic ad G et F, et revertitur ad N. Circulus autem brevis ab oriente in occidentem vertit, econverso Luna. In utroque quidem circulo est locus altus et imus. In circulo maiore est locus altus magis, scilicet a terra, remotus, imus minus.

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123 predictam regulam] artem traditam *C* 125 habet … sol] sicut et sol habet circulus proprium *C* 126 firmamenti] firma *O* 127 mediatus eius] eius medius *C* 128 sive] vel *C* ‖ sit … circuli] illius sit circuli *C* 129 secundum firmamentum] in firmamento *C* 131 sit … proprii] circuli sui sit *C* ‖ invenerimus] noverimus *C* 134 suum] *om. C* ‖ innexum et] innixtum *O* 135 generatur difficultas] difficultas generatur *C* 136 suum] *om. C* 137 diversitates] diversitatis *O* 138–139 in … minor] maiori in circuli maioris vincentis quodammodo minorem *C* 139 circuitus sui] sui circuitus *C* 140 subicimus] subiectam supposuimus *C* 144 E] alterius est T *O* ‖ autem] itaque *C* 145 luna] ab *add. C* ‖ b] d *O* ‖ d] b *O* 146 et^2] ad *C* 147 oriente … occidentem] occidente in orientem *CO* 148 econverso] et equo(?) *O*

it has the same distance 11 signs following it. The same is true of 2 [signs] and 10, 3 and 9, 4 and 8, 5 and 7, as well as 6 on either side. And this is why they have the same corrections written next to them. You will subtract them on one side, add them on the other, in accordance with the aforementioned rule.

III.ii

The Moon, as with the Sun, has its own circle on which it performs its mean motion. Its centre is 5° removed from the centre of the firmament. The mean motion [of the Moon], however, is found from a table [that was made] according to the method described [above], as with the Sun. This table is used to determine the degree or minute that it occupies on this circle. Once this has been found, one must seek the degree it occupies according to the firmament. Finding this is useful in the practice of both astrology and astronomy. For it is of little importance to know the degree it occupies on its own circle, unless we [subsequently] find the degree it occupies according to the circle of the firmament. According to Ptolemy, finding this is more difficult owing to the fact that together with its greater circle, on which it performs its mean motion, [the Moon] has a small circle that is fastened to it and has its centre on its [surface]. From this results a very great difficulty in examining its true position, seeing as it undergoes several variations of motion according to different circles. For the greater circle carries it from west to east, the smaller one in the opposite direction. Yet the smaller circle is also carried by the greater one by some amount to complete its circuit.

To make this matter clearer, we present a diagram to the eyes.[2] And we divide the greater circle into eight parts, marking it with eight letters that are placed in reverse order, just as this circle is carried from the west against an easterly direction: NMLKIHGF. The small circle, on the other hand, we divide into four parts and mark it with four letters placed in their regular order, namely, ABCD. And its centre is E and the centre of the larger [circle] is O. The Moon, for its part, is carried on the small circle from A to B, further to C, then to D, and thus returns to A, whereas on the greater circle it is carried from N to M, further to L, K, and I, then to H, then to G and F, and [then] returns to N. The small circle, however, turns from east to west, in a direction contrary to the Moon. Indeed, each of the circles has an apogee and a perigee. On the greater circle the apogee is [the point] that is most removed from the Earth, the perigee [the one that is] least [removed]. On the small circle,

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[2] See Figure 3 on p. 162.

In circulo brevi est locus altus qui superior supra maiorem circulum, imus inferior, scilicet sub maiori circulo. Et est uterque circulus 12 partes equales habens. Diameter vero minoris continet 2 gradus et 40 minuta de circulo maiori. Indi autem hunc circulum brevem esse non asserunt.

In inveniendo itaque locum directum Lune necesse est circuli maioris et minoris et circuli firmamenti equationem invenire et quot gradus circuli maioris peragens quot minoris et quot firmamenti gradus perficiat requirere. Inequaliter enim gradus horum circulorum percurrit. Die etenim uno plures gradus circuli parvi quam maioris et plures maioris quam firmamenti percurrit, interdum pauciores sui circuli maioris quam firmamenti. Quod inde provenit sicut et de Sole diximus, quia singulis | *O* 128^{v} diebus circuli sui gradus equaliter perficit, firmamenti vero inequaliter propter puncti mutationem. Et cum Luna in loco suo alto vel imo maioris circuli existens in eodem gradu circuli et sui et firmamenti existat. Inde remota in alio gradu vel minuto est sui circuli quam firmamenti et sit distantia inter gradus crescens usque ad quadratum cum est Luna a loco alto ad imum procedens. Et tunc est maxima cum est in medio loco alti et imi, scilicet in quadrato, equaliter distans ab utroque. Fitque tunc differentia 5 graduum secundum punctum et vincit Luna in gradu sui circuli gradus firmamenti. Ut cum Luna distet a loco alto suo per 90 gradus in suo circulo sit in V gradus minus circuli firmamenti, acsi Luna in circulo suo esset in primo gradu Arietis ⟨et⟩ esset in 25 gradu Piscium in circulo firmamenti, scilicet distans per 5 gradus a capite Arietis in circulo firmamenti. Inde autem descendens Luna decrescit distantia, adeo ut cum pervenerit ad locum imum, iam nulla sit distantia, sed potius in eodem gradu sit et circuli sui et firmamenti. Unde item discedens versus altum locum permutat gradus et crescit differentia, item vincente Luna gradus sui circuli in gradibus firmamenti, adeo ut cum pervenerit ad quadratum in pluribus sit gradibus firmamenti quam sui circuli eadem proportione qua in alio quadrato preterierat gradus firmamenti gradibus sui circuli, acsi Luna pervenisset ad caput Libre in firmamento et esset in 25 gradu Virginis

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150 est … altus] locus altus est *C* ‖ qui] est *add. C* 151 circulus] *om. O* 154 in] *om. O* 154–155 maioris … minoris] minoris et maioris *C* 155 equationem] coequationem *C* 157 circulorum] *om. O* ‖ etenim] et *O* 158 maioris¹] magis *O* 159–160 quod … provenit] *om. O* 161 equaliter] *om. O* ‖ puncti] predictam *C* 162 suo alto] alto suo *C* 163 circuli … sui] sui circuli *C* 165 est] *om. O* ‖ procedens] descendens *C* 166 quadrato] quo tunc *O* 167 fitque] et fit *C* ‖ 5 graduum] graduum 5 *C* 168 gradus] gradum *C* 170–171 in 25 … distans] in primo gradu Arietis esset in circulo firmamenti in 25 gradu Piscium distans scilicet *C* 172 descendens] descendente *C* ‖ distantia] differentia *C*; et *O* 173 locum] *om. C* ‖ distantia] differentia *C* 174 circuli sui] sui circuli *C* 175 altum locum] locum altum *C* 177 in … sit] sit in pluribus *C* 178 qua] et *add. C*

the apogee is the [point] that is highest above the greater circle, the perigee [the one that is] lowest (i.e., below the greater circle). And each circle possesses 12 equal parts. The diameter of the smaller circle contains 2;40° of the greater one. The Indians, however, do not assert the existence of this small circle.

To find the true position of the Moon it is therefore necessary to find the equation between the greater and smaller circle and the circle of the firmament and to seek for a given number of degrees it completes on the greater circle the corresponding number of degrees it completes on the smaller [circle] and on the firmament. For it traverses the degrees of these circles in unequal times. For on a given day it traverses more degrees on the small circle than on the greater one and [sometimes] more on the greater one than on the firmament, sometimes fewer on the greater circle than on the firmament. The cause of this is the same as with the Sun, because each day it completes an equal number of degrees on its own circle, but an unequal one on the firmament, owing to the eccentricity. And when the Moon is at its apogee or perigee of the greater circle, it occupies the same degree on its own degree and on the firmament. Having subsequently moved away, it is in a different degree or minute on its circle than on the firmament and the distance between these degrees increases until it has reached quadrature as the Moon is on its way from apogee to perigee. And [the difference] is greatest when [the Moon] is at the mid-point between apogee and perigee, namely, at quadrature, having an equal distance from both. And the difference is then 5° according to the centre and the Moon's degree on its own circle surpasses the degree on the firmament, such that, when the Moon is at 90° from its apogee on its own circle, its position on the circle of the firmament is less by 5°, as if the Moon were in the first degree of Aries on its own circle and in the 25th degree of Pisces on the circle of the firmament, namely, at a distance of 5° from the head of Aries on the circle of the firmament. But as the Moon departs from this point, the distance decreases, so much so that when it has arrived at the perigee, there is no longer any distance, but it instead occupies the same degree on its own circle and on the firmament. Likewise, as it departs towards the apogee it changes degrees and the difference increases, with the Moon's degrees on the firmament surpassing those it occupies on its own circle, so much so that when it has arrived at quadrature its degrees on the firmament surpass its degrees on its circle by the same amount as the degrees on its own circle surpassed the degrees on the firmament at the other quadrature, as if the Moon had arrived at the head of Libra on the firmament and were [also] at the 25th degree of Virgo on

in circlo suo. Que item differentia decrescit dum inde recedit Luna ad locum altum, adeo ut cum illuc pervenerit nulla iam distantia existente sit in eodem gradu et sui circuli et firmamenti, acsi esset in initio Cancri sui circuli et in initio Cancri firmamenti.

Quoniam vero Ptolomeus comperit interdum maiorem distantiam esse cum perveniret Luna prope quadratum loci alti, interdum minorem, et similiter in aliis partibus circuli non equalem semper provenire distantiam et prope locum altum et imum nunc maiorem, nunc minorem esse distantiam, animadvertit Lunam circulum brevem habere et secundum ipsum eiusmodi crementa et decrementa distantie provenire, cum secundum ipsum locum altum in circulo maiore deberent in eisdem locis semper equaliter provenire, sicut in Sole. Cum enim est in quadrato loci alti semper equalis est differentia in gradibus sui circuli et firmamenti. | *O* 129^{r}

Quem circulum hac ratione comperit. Deprehendit enim Lunam in quadrato loci alti vel imi obscurantem Solem. Constat vero quod Luna cum facit obscurationem Solis in eodem gradu est firmamenti cum Sole iuncta. Hec est enim recta coniunctio Solis et Lune que secundum eundem gradum firmamenti fit. Cum vero in eodem gradu essent in obscuratione deprehendit distantiam esse 5 graduum a gradu in quo erat in circulo suo ad gradum firmamenti in quo erat, tamquam si esset obscuratio Solis in capite alicuius signi, in quo Luna sibi esset coniuncta, et esset Luna tunc in 5 gradu in circulo suo ante vel plus. Vel etiam idem per stellam fixam deprehendit, ut cum Luna coniuncta cordi Leonis eius obscurationem faceret in eodem gradu cum ipso existens et in circulo suo existens in 5 gradus plus vel minus esset cum esset in quadrato loci alti. His igitur duobus modis comprehendit Ptolomeus distantiam esse 5 graduum, per obscurationem Solis et per fixam stellam, et hanc esse maximam secundum punctum quando Luna erat in quadrato loci alti. Sed quoniam iterum comprehendit distantiam prope quadratum Luna existente maiorem esse, animadvertit ipsam habere circulum

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181 nulla] sit *add. O* ‖ distantia existente] existente differentia *C* 182 et^{1}] *om. O* 183 firmamenti] in firmamento *C* 184 distantiam] differentiam *C* 185 interdum minorem] *om. O* 186 non] nec *O* ‖ distantiam] differentiam *C* 187 distantiam] differentiam *C* 188 eiusmodi] huiusmodi *C* 189 crementa] incrementa *C* ‖ distantie] differentie *C* 190 eisdem] eis *C* ‖ semper equaliter] equaliter semper *C* 191 enim] *om. C* 192 in gradibus] inter gradus *C* 193 enim] *om. C* 194 obscurantem] oppositione sui obscurare *C* 195 iuncta] coniuncta *C* 197 vero] *om. O* 198 distantiam] differentiam *C* 199 si … solis] obscuratio solis esset *C* 200 luna sibi] sibi luna *C* 201 idem … fixam] per stellam fixam idem *C* 203 ipso] *om. C* 204 modis] vel altero *add. C* ‖ comprehendit] deprehendit *C* 205 distantiam] differentiam *C* ‖ solis] scilicet *C* 207–208 iterum … quadratum] ita deprehendit differentiam prope quadratum luna *C*

its own circle. This difference decreases again as the Moon afterwards turns back towards the apogee, so much so that when it has arrived there, there is no longer any gap [and] it [then] occupies the same degree on its own circle and on the firmament, as if it were at beginning of Cancer on its own circle and at the beginning of Cancer on the firmament.

But since Ptolemy found that there is sometimes a greater gap when the Moon has arrived near quadrature from the apogee, sometimes a smaller one, and that it is also true of other parts of the circle that the same gap does not always arise and that the gap near the apogee and perigee is now greater, now smaller, he judged the Moon to have a small circle and that it is the cause of these sorts of increases and decreases, whereas according to the apogee on the greater circle the same [gaps] should always result at the same places, as with the Sun. For when it is at quadrature from the apogee, there is always the same difference between the degrees on its own circle and on the firmament.

He found this [small] circle by the following reasoning. For he seized on the Moon when it was at quadrature from the apogee or perigee while eclipsing the Sun. It is a fact, however, that the Moon, when it eclipses the Sun, is joined with the Sun in the same degree on the firmament. For the true conjunction of the Sun and Moon is the one that happens according to the same degree on the firmament. Now, when they were in the same degree during the eclipse, he determined there to be a gap of 5° between [the Moon's] degree on its own circle and the degree it occupied on the firmament, as when the eclipse of the Sun (at which the Moon is in conjunction with it) was at the head of some sign and the Moon's position on its own circle was 5° before or after. Or he determined the same thing by means of a fixed star, as when the Moon, being at quadrature from the apogee, was at the same degree as the heart of the Leon while obscuring it during a conjunction and [at the same time] was 5° behind or ahead on its own circle. By these two methods—solar eclipse and fixed star—Ptolemy recognized that there is a gap of 5°, and that this was the greatest [gap] according to the centre, when the Moon was at quadrature from the apogee. But since he found at another time that the gap when the Moon was near quadrature was greater, he judged

parvum ex cuius motu proveniret hec intensio. Inde est quod oportet Lune directum locum invenire secundum circulum parvum et secundum punctum.

Compertum autem est Luna semper coniungi Soli et opponi ipsi in loco alto minoris circuli. Tum etiam compertum est in circulo minori ferri Lunam contra maiorem, quoniam discedens a loco alto suo, cum pervenit prope quadratum, sic etiam quod est in quadrato loci alti minoris in quo fuerit coniuncta Soli, maiorem facit differentiam quam si esset versus aliud quadratum loci alti minoris. Quod patet in figura superiori, quia cum discederet ab N versus I et sit in M coniuncta Soli in loco qui est A, cum est prope L maiorem facit distantiam ad gradus firmamenti eo quod pervenit in circulo minori ad B quam si esset ab A ad D. Facit enim distantiam ad firmamentum 7 graduum et 40 minutorum, scilicet 2 gradus plus quam rectam distantiam secundum punctum, scilicet 5 gradus. Si vero processisset ab A ad D, ibi faceret minorem distantiam quam 5 graduum.

Est et alius circulus brevis secundum Ptolomeum habens centrum idem quod et circulus signorum, in quo circulo est centrum maioris circuli predicti. Quod centrum prestat aliam varietatem motus Lune per motum suum et sui circuli, scilicet in quo est et movetur movente illo circulo. Sunt et alii circuli quamplures a Ptolomeo designati ad demonstrandum varietates multiplices Lune. | *O* 129^{v}

His prelibatis sciendum quod si Luna fuerit in loco alto suo vel imo non habet directionem secundum punctum. Si fuerit in loco alto vel imo minoris, non habet directionem nisi secundum punctum | *C* 72^{v}, id est, nisi talem qualem secundum punctum habere debet, quia locus altus vel imus est in directo eiusdem loci firmamenti in cuius directo est gradus ille circuli maioris in quo est. Et quoniam directiones Solis et Lune et planetarum secundum locum altum considerantur, secundum cuius partem sunt sumenda ea que debent addi vel minui ad directionem faciendam, invento cursu mediato Lune, id est in quot gradibus vel signis vel minutis sit ab initio Arietis remota, invenienda est ipsius Lune pars, id est inveniendum est in qua parte loci alti sit, scilicet an in ea que est ab alto ad imum, an in ea que est ab imo ad altum, ut

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212 autem] vero *C* 213 tum] inde *C* ‖ ferri lunam] lunam ferri *C* 215 quadratum] *om. C* ‖ etiam] ibi *O* 215–216 fuerit coniuncta] coniunctior *C* 217 quod] que *O* ‖ discederet] descendit *C* 218 i] prope l *C* ‖ sit] sic *C* ‖ coniuncta soli] soli coniuncta *C* ‖ loco] alto minori *add. C* 219 distantiam] differentiam *C* 220 esset] et *O* 221–222 plus … gradus] *om. per. hom. O* 221 distantiam] differentiam *C* 223 distantiam] differentiam *C* 226 centrum] *om. C* 227 et] etiam *O* ‖ scilicet] *om. O* ‖ illo circulo] circulo illo *C* 228 designati] assignati *C* 233 locus altus] altus locus *C* 234–235 in … est] *om. C* 235–236 locum altum] altum locum *C* 238–241 invenienda … remota] *om. per. hom. O*

it to have a small circle whose motion was the cause of this change. This is the reason why one must find the true position of the Moon according to the small circle as well as according to the centre.

It has been ascertained, however, that the Moon is always at the apogee of the smaller circle when it undergoes conjunction and opposition with the Sun. It has thereupon also been ascertained that the Moon is carried on the smaller circle against [the direction of] the greater one, seeing as when it has arrived near the point of quadrature after departing from the apogee, in such a way that it is also at quadrature from the apogee of the small circle, where it was in conjunction with the Sun, this makes for a greater difference than if it were towards the other quadrature of the small circle. This can be seen from the diagram above, because when it has departed from N towards I and is located at M while being in conjunction with the Sun at point A, its arrival at B on the smaller circle when it is near L makes a greater gap with respect to the firmament than if it were [moving] from A to D. For the gap it makes with respect to the firmament is 7;40°, which 2° more than what the correct gap would be according to the centre, which is 5°. But if it had advanced from A to D, it would make a gap at this point that is smaller than 5°.

And according to Ptolemy there is also another small circle that is concentric with the zodiac, on which the centre of the aforementioned greater circle is located. This centre is responsible for another variation in the motion of the Moon, which stems from its motion and [the motion] of its circle, namely, the circle on which it is located and on which it is moved as a result of the motion of this circle. There are also several other circles that Ptolemy describes to demonstrate the multiple variations of the Moon.

With these points in mind, one should know that when the Moon is at its apogee or perigee it has no correction according to the centre. When it is at the apogee or perigee of the smaller [circle], it only has a correction according to the centre, that is, only the correction that it must have according to the centre [of the greater circle], because the apogee or perigee faces the point of the firmament that faces its degree on the greater circle. And since the corrections of the Sun and Moon and planets are computed according to the apogee, according to whose part one must take the amounts that must be added or subtracted to make the correction, it follows that once one has found the mean motion of the Moon (that is, by how many degrees or signs or minutes it is removed from the beginning of Aries), one must find the part of the Moon—that is, one must find in which part [of the circle] it is with respect to the apogee, namely, whether it is in [the part] from apogee to perigee, or in that from perigee to apogee—in order to know its distance from

sciatur quantum sit remota a loco alto. Quod invenitur per tabulam partis, quia secundum quod est remota a loco alto est faciendum additio vel diminutio sicut et in Sole.

Invento autem quantum Luna remota sit ab Ariete per tabulam cursus mediati, comperto etiam quantum sit remota a loco alto, requirendum est quantum distet a Sole cui coniuncta fuit. Et ideo in regula directionis docetur ut cursus Solis a cursu Lune minuatur, quia Sol unum gradum semper in die perficit, Luna vero 13 gradus cum minutis. Unde, si coniuncta fuerint prius Sol et Lune, in die uno vincit Luna Solem 12 gradibus cum minutis et tantum iam est remota Luna a Sole, scilicet per 12 gradus, biduo vero per 24 gradus. Ideo vero requiritur remotio Solis a Luna, ut illa remotio dupletur et per eam in tabula directionis queratur directio puncti. Et illam vocamus duplam remotionem, scilicet Lune a Sole duplum, que convenit uni circulorum parvorum.

Per hanc itaque duplam remotionem intramus tabulam directionis et assumimus gradus et minuta directionis puncti quod addendo vel minuendo parti Lune illam partem dirigimus. Assumimus et minuta proportionis, que sic vocantur quoniam secundum proportionem quam ipsa habent ad 60 assumendum est de gradibus et minutis circuli parvi. Deinde per partem intramus directam et assumimus gradus et minuta directionis circuli parvi et gradus partis Lune et ducimus gradus et minuta circuli parvi in minuta proportionis prius sumpta et dividimus per 60, quod tantundem valet acsi secundum proportionem quam habent mintua assumpta ad 60 tantundem assumeremus de gradibus et minutis circuli parvi. Deinde quod inde colligitur addimus semper parti Lune et quod inde colligitur addimus vel minuimus cursui mediato secundum artem directionis sicut et in Sole. Et inde locum Lune directum habemus.

Illud vero sciendum quod cum Luna discedens a loco suo alto perficit 13 gradus cum 10 minutis, locus altus interim movetur inde ubi fuerat per 6 minuta. Et singulis diebus tantundem. Unde biduo iam remotus est per 12 minuta, triduo per 18 et singulis diebus tantum est remotus quanta fuerit dif-

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241 quantum] quam *C* ‖ invenitur] invenietur *C* 242 faciendum] *om. C* 242–243 diminutio] remotio *C* 244 luna] *om. O* 245 remota] *om. C* 247 unum … semper] unumquemque gradum fere *C* 250 remota luna] luna remota *C* 251 vero requiritur] inquiritur *O* ‖ solis … luna] lune a sole *C* 253 lune … duplum] remotionis lune duplum a sole *C* 255 duplam remotionem] remotionem duplam *C* ‖ tabulam directionis] directionis tabulam *C* 256 quod] quos *C* 257 et] etiam *C* 258 quoniam] quia *C* 260 intramus directam] directam intramus *C* ‖ directionis] *om. O* 262 per] in *C* 262–264 quod … parvi] *om. O* 265 semper] vel minuimus *add. O* ‖ parti] gradibus partis *C* 268 cum] dum *C* ‖ suo alto] alto suo *C* 269 ubi] unde *O* 271–272 quanta … partis] *gem. O*

the apogee. This is found by using the table of the anomaly [*tabulam partis*], because one must make an addition or subtraction in accordance with its distance from the apogee, as with the Sun.

Once one has found the Moon's distance from Aries with the mean-motion table and has also ascertained its distance from the apogee, one must seek its distance from the Sun [after] having been in conjunction with it. And to this end the rule for the correction teaches to subtract the solar motion from the lunar motion, seeing as the Sun always completes one degree per day, whereas the Moon [completes] 13 degrees with some minutes. It follows from this that if the Sun and Moon were previously in conjunction, the Moon surpasses the Sun in one day by 12 degrees with some minutes and the distance between the Moon and the Sun is then already as great, namely, 12°, whereas after two days it is 24°. The purpose, however, of seeking the elongation between the Sun and Moon is so that it can be doubled and used to search in the correction table for the correction of the centre. And we call this the 'double elongation' (i.e., of the Moon from the Sun), which belongs to one of the small circles.

We consequently use this double elongation to enter the correction table and we take the degrees and minutes of the correction of the centre, which we add or subtract from the lunar anomaly [*parti Lune*] to correct it. We also take the minutes of proportion, which are thus called because their proportion with respect to 60 determines the amount we take of the degrees and minutes of the small circle. Next, we enter [the table] with the true anomaly and take the degrees and minutes of the correction of the small circle and the degrees of the [correction of the] lunar anomaly, and we multiply the degrees and minutes of the small circle by the minutes of proportion that we took earlier and divide the whole by 60, which amounts to the same as taking a portion of the degrees and minutes of the small circle that corresponds to the ratio between the minutes [of proportion] that we took and 60. Next, we always add what we have gathered this way to the lunar anomaly and then add or subtract the result from the mean motion according to the art of [computing] the correction, as with the Sun. And from this we get the true position of the Moon.

One should know, however, that as the Moon completes 13;10° in departing from its apogee, the apogee meanwhile moves 0;6° away from where it was. And this happens every day. In two days, it has consequently already reached a distance of 0;12°, in three days of 0;18°, and every day its distance

O 101^{r} ferentia partis | et cursus mediati. Et semper pars tantundem movetur, equa tamen proportione se habens ad locum altum. Et quantumcumque moveatur locus altus, semper pars eius dicitur una a presenti loco alto ad imum, altera a presenti imo ad altum. Et quoniam sic mutatur altus locus, citius redit ad punctum quam ad locum altum, citius etiam ad locum altum quam ad Solem a Sole. Et propter tantam mutationem loci alti facta est tabula partis, per quam comprehenditur quantum remota sit a loco alto. Quod in Sole facere non oportuit propter parvam mutationem sui loci alti, licet quidam tabulam partis Solis composuerunt, sicut et Lune.

Indi, non asserentes circulum brevem, per partem solum locum directum inveniunt, intrantes per partem et suscipientes in ordine graduum et minutorum partis Lune numerum adiacentem parti invente. Quem deinde minuunt a cursu mediato, si pars fuerit minus 6 signis, addunt, si plus fuerit. Et inde colligunt locum directum.

⟨III.iii⟩

Saturnus habet circulum maiorem habentem punctum egressum a puncto firmamenti et terre, in quo facit cursum suum medium, cuius partes ⟨vel⟩ 12 signa equali temporis spatio peragrat. Inequaliter autem partes firmamenti pertransit propter mutationem puncti, sicut Sol et Luna. Secundum quod videtur nunc velocior, nunc tardior, quoniam equales partes firmamenti percurrit has citius, illas tardius. Habet etiam locum altum, qui dicitur ‘augis’, et imum, id est augis oppositum, quod est nadir, in circulo suo. In quibus cum fuerit, erit in eisdem gradibus et sui circuli et firmamenti. Inde discedens vel illuc accedens semper est in alio gradu vel minuto circuli sui quam firmamenti, et nunc in pluribus sui circuli quam firmamenti, nunc in paucioribus, facta supputatione a loco alto, sicut in Sole et Luna demonstravimus. Ad comperiendum gradum firmamenti in quo fuerit, oportet scire locum suum in circulo suo et illum adequare loco suo in firmamento, ut sciatur quem gradum sui circuli tenens quem gradum vel minutum firmamenti teneat.

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273 et] quia *O* 274 alto] altum *O* 275 altus locus] locus altus *C* 276 citius … altum] *om. per hom. O* 278 comprehenditur] deprehenditur *C* ‖ sit] *om. O* 279 propter] per *O* 281 per] propter *C* ‖ partem] artem *O* 282 inveniunt] invenerunt *C* ‖ partem] partes *O* 283 quem deinde] quemadmodum *O* 287 maiorem] rectum *O* 288 firmamenti] firmo *O* ‖ suum] *om. C* 289 temporis spatio] spatio temporis *C* 290 propter] per *O* 291 videtur nunc] nunc videtur *C* 292 habet] hunc *O* 293 oppositum] oppositio *C* ‖ nadir] nadayr *C* 295 minuto] merito *O* ‖ circuli sui] sui circuli *C* 297–298 ad comperiendum] unde ad aperiendum *C*

increases by the difference between the anomaly and the mean motion. And the anomaly always increases by this rate while retaining an equal proportion to the apogee. And no matter how much the apogee has moved, one always says that there is one part from the present apogee to the perigee, another from the present perigee to the apogee. And since the apogee changes in this fashion, [the Moon] returns more quickly to a point [on its own circle] than to the apogee [and] also more quickly to the apogee than to the Sun. And this change in the position of the apogee is the reason behind the creation of the table for the anomaly, which is used to seize [the Moon's] elongation from the apogee. It was not necessary to make [such a table] for the Sun, owing to the small change of its apogee, notwithstanding the fact that certain have people constructed a table for the solar anomaly, in analogy with the Moon.

The Indians, who do not assert the existence of the small circle, only use the anomaly to find the true position, by entering [the correction table] with the anomaly and taking in the column for the degrees and minutes of the lunar anomaly the number adjacent to the anomaly that has been found. They subsequently subtract this [number] from the mean motion, if the anomaly is less than 6 signs, or add it, if it is more. And from this they gather the true position.

III.iii

Saturn has a greater circle with a centre eccentric to the centre of the firmament and the Earth, on which it performs its mean motion, traversing [each of] its parts or 12 signs in an equal amount of time. The parts of the firmament, by contrast, it traverses unequally as a result of the eccentricity, as with the Sun and Moon. It accordingly appears to move, now more swiftly, now more slowly, because it runs through some equal parts of the firmament more quickly, through others more slowly. It also has on its circle an apogee, called 'aux', and a perigee (i.e., the point opposite the aux), which is the nadir. When it is at these [points], its degree on its own circle and on the firmament will be the same. Afterwards, as it descends towards the one or ascends towards the other, it is always in a different degree or minute on its own circle than on the firmament, and it sometimes has more [degrees] on its own circle than on the firmament, sometimes less, as reckoned from the apogee, just as we have shown for the Sun and Moon. In order to ascertain the degree on the firmament it occupies, one must know its position on its own circle and make it equal with its position on the firmament so as to know which degree occupied by it on its own circle corresponds to which degree or minute on the firmament.

Habet etiam Saturnus circulum parvum in quo corpus ipsius in circuitu fertur habentem punctum suum in circulo predicto. Et cum eodem fertur ab occidente in orientem. In quo circulo habet locum altum et imum et circuit ipsum totum in diebus 378 cum horis aliquot. Quod si diviseris 360 gradus minoris circuli solutos in minuta per 378 dies, provenient singulis diebus 57 minuta. Unde Saturnus singulis diebus dicitur perficere 57 minuta in circulo minori et emensis diebus 378 redire ad locum altum illius circuli. In circulo autem maiori diebus singulis facit 2 minuta, quia tantum movetur punctum minoris circuli quaque die in circulo maiori conferente circulum minorem. Unde in die tantum movetur in duobus illis circulis quantum Sol in suo circulo, id est 59 minuta.

Deprehensum est quidem Solem coniungi Saturno existente in loco alto circuli parvi et esse illos in eodem gradu firmamenti et emenso circulo suo in 13 diebus supra consequi Saturnum. Unde constat in 378 diebus illam iterari coniunctionem. Denuo postquam | *O* 101^{v} discessit Sol ab illo utpote velocior consequitur ipsum totidem diebus existentem in loco alto circuli parvi tot diebus ab illo peractis. Dum vero circuit Saturnus tantum circulum minorem in circulo maiori aliquot gradus perficit. Et punctum minoris a loco ⟨alto⟩ maioris per totidem gradus est | *C* 73^{r} remotum in illo temporis spatio. Et cum Saturni corpus semper feratur in circulo minori, semper tamen secundum cursum medium dicitur esse in circulo maiori. Et in illo gradu ipsius est in cuius directo existit in circulo minori. Punctum quidem ipsum, cum est in auge maioris, nullam habet differentiam ad gradus firmamenti, sed in eodem gradu est circuli maioris et in firmamento. Et Saturnus cum in auge est, in illo puncto est existens sine omni differentia ad gradus firmamenti. Punctum vero inde movens iam incipit differentiam habere ad gradus firmamenti, vincens ipsos in VI signis ab auge supputatis, sicut et in Sole, ultra VI signa vincendum, donec adequantur gradus in auge, sicut et in nadir.

Et quoniam Saturnus dupliciter movetur, uno quidem modo in circulo minori et alio per circulum maiorem ferentem circulum minorem et ipsum et punctum quod movetur in ipso progrediendo, aliter oportuit eius directio-

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301 parvum] partium *O* 302 punctum] partium *O* 303 locum] suum *add. et del. O* 306 singulis diebus] *om. C* 307 et] quia *O* 309 conferente] circumferente *C* 312 est quidem] siquidem est *C* 314–315 iterari] mutari *O* 316 ipsum] *om. O* ‖ existentem] existente *O* 317 illo] ipso *C* 320 semper feratur] feratur semper *C* 321 cursum medium] medium cursum *C* ‖ maiori] maiore *O* 322 minori] minore *O* 323 maioris] mogeris *O* ‖ gradus] gradum *C* 324 in firmamento] firmamenti *C* ‖ Saturnus] *om. C* 325 gradus] gradum *C* 326 gradus] gradum *C* 327 supputatis] supputans *O* 328 vincendum] vincendus *C* ‖ adequantur] adsequuntur *O* ‖ et] *om. O* 329 quidem] *om. C* 330–331 ipsum et] ipsius *C* 331–332 eius ... inquirere] inquirere eius directionem *C*

Saturn also has a small circle that has its centre on the aforementioned circle. The body [of Saturn] revolves on [this small circle]. And it is carried with it from west to east. It has on this circle an apogee and a perigee and it goes around it in 378 days with some hours. And if you convert the 360° of the small circle into minutes [and] divide them by 378 days, each day will receive 0;57°. Saturn accordingly is said to complete 0;57° per day on the smaller circle and to return to the apogee of this circle after 378 days have been completed. On the greater circle, by contrast, it covers 0;2° per day, because this is by how much the centre of the smaller circle moves every day on the greater circle that carries around the smaller circle. Its daily motion on these two circles is consequently the same as that of the Sun on its own circle, namely, 0;59°.

It has been determined that the Sun is in conjunction with Saturn when the latter is at the apogee of the small circle and that these are [then] in the same degree on the firmament, and that once [the Sun] has measured out its circle, it takes another 13 days for it to catch up with Saturn. It is therefore evident that this conjunction is repeated every 378 days. The Sun, inasmuch as it is faster, takes this number of days after departing from [Saturn] to once more catch up with it while it is located at the apogee of the small circle. Yet, while the Saturn makes a full revolution on the smaller circle, it [also] completes a certain number of degrees on the greater circle. And the centre of the smaller one has moved with respect to the apogee of the greater one by this number of degrees in this time span. And even though the body of Saturn is always carried on the smaller circle, according to its mean motion it is always said to be on the greater circle. And its degree on this [circle] is the one it faces as it lies on the smaller circle. While the centre [of the smaller circle] is at the apogee of the greater [circle], it has no difference with respect to the degrees on the firmament, but instead occupies the same degree on the greater circle and on the firmament. And if Saturn is at the apogee [of the smaller circle], its position corresponds to that of the centre without there being any difference from the degrees on the firmament. As the centre departs, however, it already begins to have a difference with respect to the degrees on the firmament, surpassing them during [the first] 6 signs reckoned from the apogee, as with the Sun, and being surpassed by them when beyond [the first] 6 signs until the degrees become equal again at the apogee, as is also the case at the perigee [*in nadir*].

And since Saturn moves in two ways—namely, one way on the smaller circle and in another via the greater circle carrying the small circle and moving forward both it and the centre that moves on it—it will be necessary to

nem inquirere quam Solis, quoniam et secundum punctum et secundum circulum minorem movetur. Ad hoc autem laboratur ut locus ipsius secundum firmamentum inveniatur. Ad quod inveniendum sunt duo primum necessaria, ut scilicet sciatur que sit distantia ipsius ad locum altum circuli parvi et distantia puncti ab auge illius, scilicet puncti quod est circuli minoris in circulo maiori. Et per hec duo invenietur quantum distet Saturnus a gradu illo firmamenti sub quo fuit coniunctio ipsius et Solis in loco alto minoris circuli facta.

His compertis iam patuit via ad directionem qualem in sequenti explicabimus. Prima duo sic investigandi sunt. Primum querendum est quantum distet a loco alto minoris circuli, quod per cursum Solis invenitur. Quia, ut prediximus, cum in loco alto fuerit coniunctio et Sol ipso sit velocior, cum minuerimus cursum Saturni medium de cursu Solis medio, quod relinquitur est cursus Saturni in circulo parvo a loco alto et distantia ipsius ad locum altum. Sit enim ut Sol fuerit coniunctus Saturno existente in capite Capricorni in circulo maiori et hec coniunctio est in loco alto minoris circulis, quia semper ibi sit, ut diximus. Et hec tamen coniunctio in gradu firmamenti non fuit in capite Capricorni, potius in alio secundum directionem puncti. Sol abinde discedens in die perficit in circulo suo 59 minuta. Saturnus 57 minuta in circulo parvo. Secundum punctum suum quod est in circulo maiore perficit duo minuta cursu mediato secundum maiorem circulum. Itaque hic cursus mediatus Saturni minuatur a cursu solis diurno. Et relinquitur 57 minuta, quod est cursus Saturni in circulo minore. Constat igitur Saturnum distare a loco alto circuli parvi 57 minutis et hoc vocatur 'pars' circuli parvi.

Et quia coniunctio fuerat in alio gradu firmamenti quam circuli, requirendum est quantum distet ab illo gradu. Quod sic invenitur. Inquirendum est | *O* 102^{r} quantum distet punctum ab auge, quod diximus unum esse inquirendorum. Quod fit minuendo locum altum a cursu mediato puncti, quia quod reliquum fuerit erit distantia puncti ad augem. Et illam distantiam 'punctum' vocamus, quod in Sole et Luna vocabatur pars. Quod habeat directionem suam, vel maiorem, vel minorem, vel addendam, vel minuendam secundum

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332 quoniam] quam *O* 333 movetur] *om. C* 334 sunt] *om. O* ‖ primum] primo *C* 337 maiori] maioris *O* 340 his] autem *add. C* 342 invenitur] invenietur *C* 342–343 ut … cum] ut cum prediximus *O* 344 de] a *C* 345 cursus] circulus *O* 346 existente] existenti *C* 347 maiori] maiore *C*; *om. O* 348 quia … ibi] ubi semper *C* ‖ gradu] gradum *O* 350 59] LVIII *O* 351 57] LVIII *O* 352 maiorem circulum] circulum maiorem *C* 353 itaque … minuatur] minuatur itaque hic cursus mediatus Saturni *C* 353–354 et relinquitur] relinquuntur *C* 357 et] *om. C* 357–358 requirendum est] est requirendum *O* 358 quod] qui *O* 359 unum] *om. O* 361 erit] in *add. O* 362 Sole] Sol *O* ‖ quod] punctum *add. C* 363 addendam] addenda *O*

investigate its correction in a different way than for the Sun, because it moves both according to the centre and according to the smaller circle. The goal of the operation, however, is to find its position according to the firmament. To find this, two things are necessary first, namely, to know its distance from the apogee of the small circle and the distance of the centre from its apogee, that is, the centre that belongs to the small circle on the greater circle. And by means of these two [distances] one can find the distance of Saturn from the degree on the firmament under which took place its conjunction with the Sun while it was at the apogee of the smaller circle.

By ascertaining these things, one has already opened a path towards [computing] the correction, which we shall explain in what follows. Two things must be investigated first, as follows. First one must seek the distance [of the planet] from the apogee of the smaller circle, which is found via the motion of the Sun. For since (as we have said before) the conjunction was at the apogee and the Sun is faster than [Saturn], once we have subtracted the mean motion of Saturn from the mean motion of the Sun, the remainder is Saturn's motion on the small circle with respect to the apogee and its distance from the apogee. For let us assume that the Sun is in conjunction with Saturn while [Saturn] is at the head of Capricorn on the greater circle and that this conjunction takes place at the apogee of the smaller circle, because it always takes place there, as we have said. And this conjunction was nevertheless not at the head of Capricorn on the firmament, but rather at another degree according to the correction of the centre. Departing subsequently, the Sun completes 0;59° on its circle in a day. Saturn [completes] 0;57° on the small circle. According to its centre located on the greater circle it completes 0;2° of mean motion according to the greater circle. One must therefore subtract Saturn's mean motion from the daily solar motion. And the remainder is 0;57°, which is Saturn's motion on the smaller circle. It is evident, then, that Saturn is removed by 0;57° from the apogee of the small circle, and this is called the 'anomaly' [*pars*] of the small circle.

And since the conjunction was in a different degree on the firmament than on the circle, one must seek its distance from this degree. This is found as follows. One must investigate the distance between the centre and the apogee, which we have already stated to be one of the things that need to be investigated. This is done by subtracting the apogee from the mean motion of the centre, because the remainder will be the distance of the centre from the apogee. And we call this distance the 'centre', which [is the same as what] was called 'anomaly' [*pars*] in the case of the Sun and Moon. It has its own correction, greater or smaller, that must either be added or subtrac-

quantitatem suam, ut in predictis, addendam scilicet, si fuerit plus 6 signis, minuendam, si minus. Et est directio maxima cum fuerit punctum in quadrato loci alti.

Quanta vero directio adiaceat uni gradui sive pluribus est deprehensum a sapientibus secundum rationem arcus et corde. Et ascribatur in tabulis cuique graduum numero sua directio. Invento itaque puncto requirenda est in tabulis in ipsius linea directio adiacens. Que cum minuitur ab ipso puncto addenda est parti circuli parvi, quia quanto minor est distantia puncti ab auge secundum gradus firmamenti quam secundum sui circuli gradus, tanto maior est distantia Saturni a gradu firmamenti in quo fuit coniunctio ipsius et Solis in firmamento quam a loco alto circuli parvi. Item addenda est directio puncto, minuenda est a parte, quia quanto maior est distantia puncti ab auge secundum gradus firmamenti quam secundum gradus sui circuli, tanto minor est distantia Saturni a gradu firmamenti in quo fuit coniunctio quam a loco alto circuli parvi. Sic itaque una et eadem directione dirigitur punctum et pars et invenitur et quanta sit distantia puncti secundum gradus firmamenti ab auge et quantum distet Saturnus a gradu firmamenti in quo fuerit coniunctio cum erat ipse in loco alto circuli parvi.

Illum etiam sciendum est ad evidentiam directionis quod cum punctum circuli parvi singulis diebus progrediatur per duo minuta maioris circuli et Saturnus in circulo brevi 57 minuta, interdum precedit ipse punctum crescente, interdum preceditur a puncto. Recedens enim a loco alto minoris qui est in directo puncti semper superat punctum crescente semper superatione donec perfecerit 90 gradus circuli minoris. Tunc autem est corpus ipsius in circulo maiori sicut et punctum et est eius distantia ad punctum suum tunc 6 gradus et 13 minuta. Deinde tendens ad oppositum loci alti superat quidem donec perveniat ad oppositum loci alti, decrescente tamen superatione precedenti maxima, paulatim adeo ut in opposito loci alti existens nec superet punctum, nec superetur ab eo, sed in eodem gradu sint secundum firmamentum. Deinde superatur a puncto crescente superatione puncti usque in aliud quadratum. Et tunc est maxima. Et tunc corpus Saturni item est in

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364 fuerit] fuerint *O* 365 minuendam] minuenda *O* 367 adiaceat] adieceat *O* 368 corde] cote *O* ‖ ascribatur] ascribitur *C* 368–369 cuique] cuiusque *O* 369 sua] sicut *O* ‖ itaque] in *add. O* 370 cum minuitur] communiter *O* 372 sui circuli gradus] gradus circuli sui *C* 374 in] *om. C* ‖ alto] *om. C* ‖ parvi] *om. O* 375–376 ab auge] ad augem *C* 379 gradus] gradum *C* 380 fuerit] fuit *C* 381 erat] esset *C* 382 illum etiam] illud *C* ‖ punctum] puncto *O* 383 circuli^2] *om. O* 384 interdum] *om. O* 384–385 precedit ... crescente] ipse precedit punctum *C* 385 preceditur] precedetur *O* 386 puncti] puncto *C* 387 90] XIX *O* 388 eius] *om. O* 390 loci alti] alti loci *O* 391 opposito] oppositione *C* 392 ab eo] *om. O* ‖ in eodem] in eo *O* 392–393 secundum firmamentum] firmamenti *C* 393 superatur] separatur *O*

ted according to its amount, as stated earlier, namely, it must be added if it is more than 6 signs, subtracted, if less. And the correction is greatest when the centre is at quadrature from the apogee.

But the amount of the correction that must be [placed] adjacent to one or more degrees has been determined by the sages via the method of arc and chord. And each number of degrees has its correction ascribed to it in the tables. Once the centre has been found, one must consequently seek in the tables the correction adjacent to it in its line. If this [correction] is subtracted from the centre, it must be added to the anomaly of the small circle, because the smaller the distance of the centre from the apogee according to degrees on the firmament compared to [the same distance] according to degrees on its own circle, the greater the distance of Saturn from the degree on the firmament where it was in conjunction with the Sun compared [to its distance] from the apogee of the small circle. Likewise, if the correction is added to the centre, it must be subtracted from the anomaly, because the greater the distance of the centre from the apogee according to degrees on the firmament compared to [the same distance] according to degree on its own circle, the smaller the distance of Saturn from the degree on the firmament where it was in conjunction with the Sun compared to [its distance] from the apogee of the small circle. In this way, then, one and the same correction is used to correct the centre and the anomaly and to find both the distance between the centre and the apogee according to the firmament and Saturn's distance from the degree of the firmament where the conjunction took place while [Saturn] was at the apogee of the small circle.

Another thing that one should know in order to understand the correction is that, as the centre of the small circle advances on the greater circle by 0;2° per day and Saturn on the small circle by 0;57° per day, [Saturn] sometimes precedes this centre as [its position] increases [and] sometimes is preceded by it. For while it is moving away from the apogee of the smaller [circle], which faces the centre, it always surpasses the centre with its lead always increasing until it has completed 90° of the smaller circle. At that point, however, its body is located on the greater circle, just like its centre, and its distance from the centre is then 6;13°. Afterwards, as it aims towards the perigee [*oppositum loci alti*], it still surpasses [the centre] until arriving at the perigee, although the preceding maximum lead is gradually decreasing, so much so that when it is at the perigee it neither surpasses the centre nor is it surpassed by it, but they are in the same degree according to the firmament. Afterwards, it is surpassed by the centre with the centre's lead increasing until [it has reached] the other quadrature. And then [the difference] is greatest. And then the body of Saturn is again on the greater circle,

circulo maiori sicut et punctum. Deinceps decrescit superatio illa donec redeat ad locum altum minoris circuli in quo item sunt in eodem gradu secundum firmamentum. Inde denuo incipit Saturnus superare punctum donec perveniat ad oppositum | *O* 102$^{\text{v}}$ et superari item donec redeat ad locum altum.

Et ut evidentius appareant que diximus et que dicturi sumus, figuram subiciemus continentem et circulum firmamenti et inferius circulum Saturni maiorem habentem punctum suum egressum a puncto firmamenti. Dividitur uterque in 12 signa distincta per litteras alphabeti ordine suo, scilicet ABCDEFGHIKLM. Incipit autem distinctio a loco alto quem augem nominavimus, unde incipit divisio signorum secundum numerum graduum. Est vero augis in X Sagittarii. Circulus quidem predictus dicitur 'excentricus' quoniam centrum | *C* 73$^{\text{v}}$ ipsius est extra centrum firmamenti et terre. Continet etiam figura predicta circulum brevem Saturni habente punctum suum in circulo maiore. Qui dicitur 'epicyclus'. In quo semper fertur corpus Saturni. Quem in quatuor partes divisimus singulas continentes XC gradus. Habentem locum altum supra excentricum imum subtus. Et quatuor ille partes distinguuntur litteris quatuor, scilicet TVXY. Et locus altus tenet T, reliqui per ordinem. Et punctum Z. Nihilominus circulus epicyclus intelligatur 360 partes habere, sicut et circulus firmamenti et circulus maior. Intelligatur itaque cum dicimus Saturnus ferri ab T in V ut feratur a loco alto ad quadratum. Et per V in X ut feratur de quadrato in oppositum loci alti. Et sic in reliquis.

Dico autem quoniam cum Saturnus est in A, scilicet in auge sua, in maxima sui tarditate est secundum firmamentum, quoniam minus perficit in die firmamenti et pauciores gradus vel minuta percurrit firmamenti quam circuli sui excentrici. Cum autem est in G vel prope in maxima sui velocitate existit quantum ad firmamentum et die plures gradus vel minuta perficit firmamenti quam excentrici. Cum vero est in D vel prope est mediocris et tantundem perficit in die firmamenti quantum et excentrici. Et ideo secundum hoc assignatur cursus eius medius in die, quia tunc equaliter apprehendit firmamenti et circuli, similiter et punctum ipsius. In circulo vero suo,

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396 locum altum] altum locum *C* 400 appareant] appareat et *C* 401 subiciemus] subiecimus *C* 402–403 dividitur] autem *add. C* 403 distincta] distantia *O* 404–405 nominavimus] dicimus *C* 407 centrum firmamenti] firmamenti centrum *C* 408–409 habente … Saturni] *om. per hom. O* 410 singulas] singule *O* 411 subtus] subitus C; subtilius *O* 412 litteris quatuor] 4 litteris *C* 413 nihilominus] tamen *add. C* 414 itaque] *om. C* 415 cum] cur *O* ‖ saturnus] *om. C* 417 autem] igitur *O* ‖ scilicet in auge sua] prope augem suam *O* 418 perficit] proficit *O* 419 in die] *om. C* ‖ minuta] minus *O* 420 circuli sui] sui circuli *C* 421 minuta perficit] *om. O* (*lac.*) 423 tantundem] tantum *C* ‖ in … firmamenti] firmamenti in die *C* 424 eius] *om. C* 424–425 apprehendit] comprehendit *C*

just like the centre. Afterwards the lead decreases until it has returned to the apogee of the smaller circle, in which they are again in the same degree according to the firmament. Then Saturn begins anew to surpass the centre until it reaches the perigee and to be surpassed in the same way until it returns to the apogee.

And to elucidate we have said and are yet to say, we shall subjoin a diagram containing both the circle of the firmament and, below it, the greater circle of Saturn, which is eccentric to the firmament.[3] Both are divided into 12 signs marked by letters of the alphabet in their [normal] order, namely, ABCDEFGHIKLM. They are marked starting at the apogee, which we have called 'aux' [*augis*], from which begins the division of the signs according to the number of degrees. The apogee [*aux*], however, is at 10° Sagittarius. The aforementioned circle is called 'the eccentre' [*excentricus*] because its centre is outside the centre of the firmament and the Earth. The aforementioned diagram also contains the small circle of Saturn that has its centre on the greater circle. It is called 'epicycle' [*epicyclus*]. The body of Saturn is always carried on [this circle]. We have divided it into four parts, each containing 90°. It has an apogee above the eccentre and a perigee below it. And these four parts are marked by four letters, TVXY. And the apogee is at T, the others follow in sequence. And the centre is at Z. The epicycle is also understood to have 360 parts, just as the circle of the firmament and the greater circle. When we say that Saturn is carried from T to V, one should accordingly understand that it is carried from the apogee to the point of quadrature. And [when we say it is carried] from V to X, [one should understand that it is carried] from the point of quadrature to the perigee. And so on for the remaining ones.

But I say that when Saturn is at A (i.e., at its apogee), it is at its slowest with respect to the firmament, because it completes less of the firmament in a day and traverses fewer degrees or minutes on the firmament than on its eccentre. When, on the other hand, it is at or near G, it is at its fastest with respect to the firmament and completes more degrees or minutes on the firmament in a day than on the eccentre. But when it is at or near D, it is at its mean [velocity] and completes in a day as much of the firmament as it does of the eccentre. And its daily mean motion is attributed to it on this basis, seeing as it then grasps equal parts of the firmament and [its own] circle, and the same applies to its centre. By contrast, on its own circle

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[3] See Figure 4 on p. 169.

ut diximus, semper equaliter, et punctum similiter, perficit, sed quantum ad firmamentum nunc plus, nunc minus et nunc tardiora videntur, nunc velociora.

Cum autem Saturnus est in T epicycli et punctum est in loco alto, id est in A excentrici, dicitur esse Saturnus et in A excentrici et in A firmamenti, quia in directo utriusque est existens supra hoc et sub illo. Et sic in ceteris locis semper esse dicitur in illo loco firmamenti et excentrici in cuius directo est existens tamen in epicyclo. Et cum Saturnus descendit ab T versus V singulis diebus superat punctum precedendo usque ad V. Cum vero est in V | *O* 103^{r} iam superavit punctum in Z 6 gradibus et 13 minutis. Sed minuitur illa superatio ab V ad X, adeo ut iam nulla sit. Et ab V usque ad X incipit retrogradari quantum ad firmamentum cum semper in anteriora epicycli feratur. Et sic usque ad Y retrogradatur. Et ab X et Y superatur a puncto suo precedente ipsum. Et est maxima superatio in Y. Que superatio decrescit donec redeat ad T. Et ibi item adequatur puncto suo secundum eundem gradum firmamenti. Precedit itaque punctum a T usque ad X et preceditur a puncto ab X usque ad T. Sed maxima precedentia est in quadrato, V et Y. Econverso evenit in gradibus excentrici, quoniam punctum ab auge A usque ad punctum G in gradibus excentrici vincit gradus firmamenti. Sed a G usque ad A vincitur a gradibus firmamenti, sicut de Sole diximus.

Sed quamvis semper equalis sit distantia inter Saturnum et punctum suum secundum gradus excentrici cum Saturnus est in V, non tamen semper equalis distantia est secundum gradus firmamenti, sed nunc minor, nunc maior, nunc equalis secundum utrosque. Quod ratione perpenditur ex precedentibus, quod plures scilicet gradus excentrici comprehendunt pauciores firmamenti, quandoque pauciores comprehendunt plures, quandoque pares. Utpote 30 gradus excentrici qui sunt ab A ad B non comprehendunt 30 gradus firmamenti qui sunt ab A ad B, sed pauciores. Item 30 gradus excentrici qui sunt ab G ad H plures gradus firmamenti capiunt, quoniam a G ad H plures, scilicet quam 30, gradus firmamenti. Ad quadrata ambo comprehendunt 6 gradus excentrici totidem firmamenti et comprehenduntur ab eis. Inde est quod cum Saturnus existens in V distans a puncto suo per 6

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426 perficit] perficiunt *O* 427–428 videntur ... velociora] nunc velociora videntur *C* 429 loco alto] alto loco *C* ‖ in] *om. O* 432 esse dicitur] dicitur esse *C* 433 V] N *O* 435 Z] *om. C* 436 iam] *om. O* 440 ibi item] ibidem *O* 441 punctum] puncto *O* ‖ a] ab *O* 442 T] Y *CO* ‖ V] T *CO* 444 gradus] gradum *C* ‖ a] ab *O* 445 sicut] ut *C*; et ut *O* 446 equalis sit] sit equalis *C* 447 gradus] gradum *C* ‖ saturnus] sol *CO* ‖ v] *om. C* 448–449 minor ... maior] maior, nunc minor *C* 451 comprehendunt] quandoque *add. C* 452 pares] pauciores *O* ‖ qui] que *O* 454 H] *om. O* 455 quam] quoniam *C* ‖ quadrata] quartam *C*; quadratam *O* 457 est] *om. O* ‖ suo] *om. C*

[Saturn] always moves at an equal rate (as we have said), and the same applies to its centre, whereas with respect to the firmament they sometimes [complete] more, sometimes less and sometimes appear slower, sometimes faster.

But in a situation where Saturn is at T of the epicycle and its centre is at the apogee (i.e., at A of the eccentre), Saturn is said to be both at A on the eccentre and at A on the firmament, because it directly faces both of them, being above one and below the other. And at other positions one always says in this way that it is at the place on the firmament and the eccentre that it directly faces, even though it is actually found on the epicycle. And when Saturn descends from T towards V it surpasses the centre with every day by preceding it until [it has arrived at] V. But when it is at V it has already surpassed the centre at Z by 6;13°. This lead, however, decreases between V and X, so much so that it disappears. And between V and X [the planet] begins to go backwards with respect to the firmament, even though it is always carried forward on the epicycle. And it keeps going backwards in this way until it is at Y. And between X and Y it is surpassed by its centre, which precedes it. And this lead reaches maximum at Y. The lead then decreases until it reaches T. And there it again occupies the same degree on the firmament as its centre. It accordingly anticipates the centre between T and X and is anticipated by it between X and T. Yet the difference is greatest at quadrature, V and Y. The reverse happens with the degrees on the eccentre, because when the centre is between the apogee, A, and point G, its degrees on the eccentre surpass the degrees on the firmament, whereas between G and A it is surpassed by the degrees on the firmament, just as we have said about the Sun.

Yet even though the distance between Saturn and its centre when Saturn is at V is always the same according to degrees on the eccentre, it is not always the same according to degrees on the firmament, but sometimes smaller, sometimes greater, sometimes the same according to both. From a careful consideration of the foregoing, it follows by way of reasoning that [sometimes] a greater number of degrees on the eccentre comprises a smaller number on the firmament, that sometimes a smaller number comprises a greater one, that sometimes they are the same. The 30 degrees on the eccentre from A to B, for example, do not comprise the 30 degrees on the firmament that are from A to B, but fewer. Likewise, the 30 degrees on the eccentre from G to H seize more degrees on the firmament, because from G to H the number of degrees on the firmament is more than 30. At both quadratures, 6 degrees on the eccentre comprise as many degrees on the firmament and are comprised by them. This is why, when Saturn is at V and has a distance of 6;13° from its centre according to the eccentre, it at one time

gradus et 13 minuta secundum excentricum, tum per totidem firmamenti differat, tum per pauciores, tum per plures. Quoniam cum fuerit in V epicycli et in auge excentrici distantia minor est secundum firmamentum quam secundum excentricum per 19 minuta. Quoniam cum per excentricum distet a puncto Z scilicet per 6 gradus et 13 minuta, non distat secundum gradus firmamenti nisi per 5 gradus et 54 minuta. Sed minuitur distantia illa cum fuerit in eodem V versus quadratum augis accedens. Quoniam si fuerit in V epicycli existens in B excentrici, non erit tanta differentia. Quod si fuerit punctum in D excentrici, scilicet quadrato augis, et fuerit planeta in V epicycli, iam nulla est minutio distantie superioris, sed equalis est distantia secundum excentricum et secundum firmamentum. Quoniam secundum utrumque est distantia per 6 gradus et 13 minuta.

Deinde crescit item distantia sicut prius minuebatur paulatim donec perventum fuerit ad G sic, scilicet, ut cum planeta fuerit in G, scilicet augis opposito, existens in V epicycli, iam maior sit distantia secundum gradus firmamenti inter planetam et punctum quam secundum excentricum per 19 minuta. Ut cum distantia sit secundum excentricum per 6 gradus et 13 minuta, sit distantia secundum firmamentum per 19 minuta plus et sit distantia secundum firmamentum per 6 gradus et 32 minuta. Et cum in auge erat distantia secundum firmamentum minor ea secundum excentricum *O* 103^{v} per 19 minuta, et erat per 5 gradus et 54 minuta, | in opposito augis maior sit per 19 minuta et sit per 6 gradus et 32 minuta. Item minuetur paulatim per singula signa in progrediendo versus K, adeo ut si punctum epicycli pervenerit ad quadratum K et Saturnus sit in predicto V epicycli, iam nulla sit minutio distantie vel crementum, sed sit eadem secundum excentricum et firmamentum, scilicet 6 graduum et 13 minuta. Inde item crescit paulatim distantia, ut proveniat maior secundum excentricum quam secundum firmamentum, donec revertatur ad augem. Et tunc 19 minuta est distantia. Et inde item incipit minui. Similiter in quocumque loco fuerit epicycli minuetur et augetur distantia secundum excentricum inter planetam et punctum a distantia que est secundum firmamentum in diversis quadrantibus.

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458 tum] tamen *O* 459 tum] tamen *O* ‖ tum] inde *O* 461 per^{1}] *om. O* ‖ 19] 17 *C*; xc *O* 462 Z … per] Z per *C*; scilicet per Z *O* ‖ distat] distet *O* 463 minuitur] minuit *O* ‖ cum] si *O* 467 est^{2}] *om. C* 468 excentricum] excentrici *O* 469 13] xiiii *O* 470 crescit item] item crescit *C* 471–472 augis opposito] oppositio augis *C* 472 maior] minor *C* 475 sit^{2}] scilicet *add. C* 476 32] 22 *C* 477 erat] esset *C* ‖ ea] ei *C* 478 erat] esset *C*; erit *O* ‖ in] cum *C* 479 6] X *O* ‖ minuta] et erat *add. O* ‖ minuetur paulatim] minuitur *C* 480 progrediendo] progradiendo *O* 483 inde] *om. C* ‖ crescit paulatim] paulatim crescit *C* 486–487 minuetur] minuitur *C* 487 et] vel *C* ‖ excentricum] et *add. C* 488 quadrantibus] quadratis *C*

differs by the same number [of degrees] on firmament, whereas at other times [it differs] by fewer [or] by more. For when it is at V of the epicycle and at the apogee of the eccentre, the distance is 0;19° less according to the firmament than according to the eccentre. For when its distance from point Z according to the eccentre is 6;13°, its distance according to the firmament is only 5;54°. Yet this gap decreases as [the planet] approaches quadrature with respect to the apogee [*augis*] while being at the same point V. For when it is at V of the epicycle and at B of the eccentre, the gap is not as great. But when the centre is at D of the eccentre (i.e., at quadrature from the apogee) and planet is at V of the epicycle, the distance above is no longer diminished, but is the same according to the eccentre and according to the firmament. For the distance according to either of them is 6;13°.

Afterwards the distance again gradually increases the same way it previously decreased until it has reached G, namely such that when the planet is at G, which is the perigee [*augis oppositio*], while [also] at V of the epicycle, the distance between the planet and the centre is already 0;19° greater according to the degrees on the firmament than according to the eccentre, such that when the distance according to the eccentre is 6;13°, it is 0;19° greater according to the firmament and the distance according to the firmament is 6;32°. And whereas the distance according to the firmament was 0;19° less than according to the eccentre, and was 5;54°, when [the planet was] at the apogee, it is 0;19° more when [the planet is] at perigee, and it is 6;32°. It will also gradually decrease with each sign as it advances towards K, so much so that when the centre of the epicycle has arrived at the point of quadrature, K, and Saturn is at the aforementioned [point] V of the epicycle, there is no longer any decrease or increase of the distance, but it will be the same according to the eccentre and the firmament, namely, 6;13°. Afterwards the distance again gradually increases, so that it becomes greater according to the eccentre than according to the firmament, until [the planet] returns to the apogee. And then the distance is [greater by] 0;19°. And afterwards it begins to decrease again. In the same vein, whatever its location on the epicycle, the distance between the planet and the centre according to the eccentre will decrease and increase with respect to the distance according to the firmament in the different quadrants.

Ad quod quidem scire convenit ⟨esse⟩ remotionem longiorem et propiorem. Est autem remotio longior maior distantia a terra et propior minor distantia a terra. Et illa pars excentrici que est a K ad A et sic usque ad D est remotio longior, id est longius a terra distans. Reliqua que est a D ad G et sic ad K est remotio propior, id est propior terre existens. In tota itaque remotione longiore est minor distantia Saturni ad punctum secundum firmamentum quam secundum excentricum. Sed in A est maxima minutio distantie, ab K crescens usque ad A, inde minuens usque ad D, ut tunc equales sint distantie. Et ab D usque ad K, que est remotio propior, maior distantia secundum firmamentum quam secundum excentricum et maioratur semper ab D usque in G, deinde minoratur | *C* 74$^{\mathrm{r}}$ usque ad K. Unde in directione precipitur ut cum supra minuta proportionis invenerimus scriptum “crescit,” sumamus minuta remotionis propioris, cum invenerimus scriptum “minuit,” sumamus minuta remotionis longioris. Quoniam illinc maior est distantia secundum firmamentum quam secundum excentricum, in remotione longiore minor.

Et quoniam, ut diximus, non equaliter semper minoratur vel maioratur distantia, est requirendum quando magis et quando minus minoretur, et quando magis et quando minus maioretur distantia. Saturnus enim ut dictum est cum est in V epicycli et in A excentrici habet minorem distantiam a puncto secundum firmamentum quam secundum excentricum per 19 minuta. Existens vero in eodem loco epicycli, scilicet in V, si fuerit in B excentrici, minorem facit distantiam ad punctum secundum firmamentum quam secundum excentricum tantum per tertiam partem [!] 19 minutorum. Cum autem existens in V epicycli fuerit in C excentrici vincitur distantia secundum firmamentum a distantia secundum | *O* 104$^{\mathrm{r}}$ excentricum tantum per duas tertias [!] 19 minutorum. Si vero existens in V epicycli pervenerit ad D firmamenti [!] et punctum fuerit in D excentrici distantia secundum firmamentum nec superatur a distantia secundum excentricum nec superat, quoniam ad quadratum pervenit in quo est mediocritas velocitatis et tardi-

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489 remotionem] remotiorem *O* ‖ et] *om. O* 489–490 propiorem] propinquiorem *O* 490 propior] propinquior *C* 491 sic] sit *O* 492 est^{1}] *om. O* 493 id ... propior] *om. per hom. O* ‖ existens] exigens *O* 496 crescens] transeuns *O* ‖ ad] *om. O* 497 que] quo *C* 498 maioratur] moratur *O* 499 d] a *C* 501 propioris] prope *O* ‖ invenerimus] viderimus *O* ‖ minuit] minuitur *C* 502 longioris] longi *O* ‖ illinc] illic *O* 503–504 longiore] longitum *C* 505 non] nunc *C* 506 est requirendum] requirendum est *C* ‖ et] *om. C* 507 et ... minus] vel *C* 507–508 enim ... est] cum est enim *O* 508 habet minorem] minorem ut dictum est habet *O* 511 distantiam] distantia *O* 513 autem] vero *C* ‖ vincitur] vicitur *O* 514 a distantia] ad distantiam *O* ‖ tantum] tamen *O* 517 a distantia] ad instantiam *O*

It is important to know in this regard that there is a farther and nearer distance. The farther distance is the greater distance from the Earth and the nearer is the smaller distance from the Earth. And the part of the eccentre that is from K to A and from there onwards to D is the farther distance, that is, the [part that is] more remote from the Earth. The remaining [part], which is from D to G and from there onwards to K, is the nearer distance, that is, the one closer to the Earth. Across the whole farther distance, the distance of Saturn from the centre is smaller according to the firmament than according to the eccentre. But the greatest diminution of the distance takes place at A. It increases between K and A, then decreases until D, such that the distances are then equal. And between D and K, which is the nearer distance, the distance according to the firmament is greater than according to the eccentre and it always increases between D and G, then decreases until K. The [rules of computing the] correction accordingly teach that when we find "increases" written above the minutes of proportion, we must take the minutes of the nearer distance, [and] when we find "decreases" written [above them], we must take the minutes of the farther distance, because in the former case the distance according to the firmament is greater than according to the eccentre, [whereas] at farther distance it is smaller.

And since, as we have said, the subtraction or addition to the distance is not always the same, one must find out when the subtraction from the distance is more and when it is less, and when the addition is more and when less. For, as has been said, when Saturn is at V on the epicycle and at A on the eccentre, its distance from the centre is 0;19° less according to the firmament than according to the eccentre. But when it is at the same place on the epicycle (i.e., at V) [and] at B on the eccentre, the distance from the centre according to the firmament is only one third of 0;19° [!] less than according to the eccentre. By contrast, when it is at V on the epicycle [and] at C on the eccentre, the distance according to the firmament is surpassed by the distance according to the eccentre by only two thirds of 0;19° [!]. But if it is at V on the epicycle [and] has arrived at D of the firmament [!] and the centre is at D of the eccentre, the distance according to the firmament is neither surpassed by the distance according to the eccentre nor surpasses it, because it has arrived at quadrature, which is the midpoint between its fastest and

atis et gradus excentrici comprehendunt totidem firmamenti. Quoniam ibi est adequatio sine omni incremento vel diminutione.

Inde vero si existat in V epicycli et attigerit E excentrici maior erit distantia secundum firmamentum quam secundum excentricum. Similiter, in quocumque gradu fuerit epicycli, si fuerit in remotione longiori minor semper erit distantia planete a puncto secundum firmamentum quam secundum excentricum. Et in eodem loco manens epicycli, si in remotione propiori fuerit, maior erit distantia secundum firmamentum quam secundum excentricum. Sed non in tota remotione longiori equaliter, potius hic multo minor, alibi parum minor. Similiter non in tota remotione propiori equaliter superans, sed hic multum superans, illic parum. Maxima autem superatio erit in auge et nadir, nulla in quadratis.

Cum itaque, ut dictum est, distantia secundum firmamentum maximam habeat minutionem a distantia secundum excentricum planeta existente in V epicycli et in A excentrici, hinc in B, illinc in M equales sunt minutiones, quoniam B et M equali proportione et remotione respiciunt A. Similiter in O et in L, quoniam eadem portione et differentia se habent ad A, hoc hinc, illud illinc, hoc ante, illud post, equales habent minutiones. Tandem hinc in D, illinc in K nulla habetur diminutio, que equaliter se habent ad A. Item cum in G excentrici existente planeta in V epicycli maxime superet distantia secundum firmamentum distantiam secundum excentricum. Equales sunt superationes in F et in H, in F crescens, in H decrescens, quoniam equales se habent ad G. Similiter in E et in I equales. In D et K nulla prorsus superatio.

Unde oportet recte dirigere volentem an sit in remotione longiori an propiori et qua in parte longioris seu propioris diligenter attendere, ut qua distantia quis superet et quis superetur, et quanto et que sit maxima superatio vel minutio comperiat. Erit itaque ordo in dirigendo ut queratur distantia planete in epicyclo a loco alto. Quod fit minuendo cursum planete a cursu

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519–520 ibi est] inest *O* 520 vel] et *O* 521 attigerit] adtingerit *O* 522 secundum] *om. O* 522–523 quocumque] quo *C* 527 in] quacumque *add. O* ‖ equaliter] minor *add. O* 528–529 superans] superas *O* 529 sed … superans] *om. per hom. O* ‖ parum] superas *add. O* 532 habeat] habet *O* 533 hinc] hic *O* ‖ minutiones] minores *O* 534 proportione] portione *O* 535 et^1] *om. O* ‖ portione] porportione *C* ‖ habent] habeant *O* 536 minutiones] mutationes *O* 538 cum] *om. C* ‖ planeta] et *add. C* ‖ maxime superet] maxima superat *C* 539 distantiam] distantia *O* ‖ excentricum] epiciclum *CO* ‖ sunt] *om. O* 540 equales] equaliter *C* 541 superatio] est *add. C* 542 oportet] te *add. O* ‖ volentem] volente *O* ‖ remotione] longitudine *O* 543 et … propioris] *om. per hom. O* 544 quis] qua *C* ‖ quis] quo *C* 545 itaque] hoc *add. C* ‖ in dirigendo] *om. O* 546 fit] sit *CO* ‖ planete] planetarum *C*

slowest motion, and the degrees of the eccentre comprise as many degrees of the firmament. For at this point they are equal without any addition or subtraction.

But when it is at V of the epicycle and subsequently arrives at E of the eccentre, the distance according to the firmament will be greater than according to the eccentre. In the same vein, in whatever degree on the epicycle it may be, if it is at farther distance, the distance of the planet from the centre will always be smaller according to the firmament than according to the eccentre. And if the [planet], while remaining in the same place on the epicycle, is at nearer distance, the distance according to the firmament will be greater than according to the eccentre. But [the difference] will not be the same across the whole farther distance, but rather it will be much greater in one place and much smaller in another. In the same vein, [the distance according to the firmament] will not surpass [the other] by the same amount across the whole nearer distance, but surpass it by a lot in one place and by a little in another. The difference, however, will be greatest at apogee and perigee, zero at quadratures.

And given that, as has been said, the distance according to the firmament is diminished by the greatest amount with respect to the distance according to the eccentre when the planet is at V on the epicycle and at A on the eccentre, it follows that the subtractions are the same when it is at B on this side and at M on the other side, because B and M are at equal distance with respect to A. Likewise, the subtraction is the same at O and L, because they differ by the same amount from A, one on this side, the other on the other side, this one before it, the other after it. There will, finally, be no subtraction at D on this side and K on the other side, which are positioned equally with respect to A. Also, when the planet is at V of the epicycle and at G of the eccentre, the amount by which the distance according to the firmament surpasses the distance according to the eccentre is greatest. The amounts are equal at F and at H, increasing at F [and] decreasing at H, because they are positioned equally with respect to G. Likewise, they are equal at E and I. There is no difference at all at D and K.

Whoever wishes to compute the correction properly must therefore pay close attention to whether [the planet] is at farther or nearer distance and to the part of the farthest or nearest distance in which it is located, so he can ascertain at which distance one surpasses the other and is surpassed by it as well as [ascertain] the maximum amount that is added or subtracted. The steps in computing the correction will therefore be [first] to seek the distance of the planet on the epicycle from the apogee [*a loco alto*], which is done by subtracting the mean motion of the planet from the motion of the

Solis propter predictam rationem. Deinde ut queratur distantia puncti ab auge. Deinde ⟨ut⟩ dirigatur punctum secundum firmamentum ut sciatur quantum distet punctum ab auge secundum gradus firmamenti. Deinde ut dirigatur pars circuli parvi secundum punctum et gradum firmamenti in quo fuit coniunctio Solis | et planete. Quod fit addendo parti quod subtrahitur puncto, vel subtrahendo parti quod additur puncto. Quibus inventis querendum est quantum distet planeta a puncto secundum gradus excentrici, ut scilicet inveniatur per distantiam ipsius a loco alto in gradibus epicycli distantia sua a puncto secundum gradus excentrici et adequatur distantia secundum epicyclum distantie secundum excentricum. Quod fit in tabulis in quibus ascribitur cuique numero graduum remotionis a loco alto epicycli numerus graduum distantie secundum excentricum a puncto ei adequatus, qui est in linea gradus circuli parvi.

O 104^{v}

Inventa autem distantia a puncto secundum excentricum requirenda est distantia secundum firmamentum ipsi adequanda. Que invenitur per additionem graduum remotionis propioris ad distantiam secundum excentricum vel per minutionem graduum remotionis longioris a distantia secundum excentricum. Quoniam per hanc additionem sive minutionem adequatur distantie secundum excentricum distantia secundum firmamentum. Quantum debeat minui sive addi distinguitur per minuta proportionis ascripta numeris graduum. Secundum quorum minutorum proportionem ad 60 debet sumi pars graduum remotionis propioris vel longioris. Hoc scilicet modo ut quota pars minuta proportionis ad 60, tota pars sumatur illorum graduum quos inveneris in eadem linea cum gradibus circuli parvi, id est sive illa minuta fuerint media pars, vel tertia, vel quarta, deinceps ad 60, sumatur media pars, vel tertia, vel quarta graduum vel minutorum remotionis propioris vel longioris. Et cum inveneris 60 minuta proportionis, significat totum debere sumi, cum 30 dimidiam, cum 20 tertiam, cum 15 quartam, et deinceps. Et istorum sumptorum additione seu minutione adequantur gradus distantie secundum excentricum et gradus distantie secundum

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547 predictam rationem] rationem predictam *O* 551 fit] sit *O* ‖ subtrahitur] subitur *O* 552 parti] *om. O* 553 gradus] gradum *C* 554 scilicet] secundum *O* 555 gradus] gradum *O* ‖ distantia] substantia *O* 556 distantie … excentricum] secundum excentricum distantie *O* ‖ fit] sit *O* 557 numero] non *O* 559 in] et *C* ‖ circuli parvi] *om. O* 560 requirenda est] secundum equirenda *O* 563 longioris] prolongioris *O* 564 additionem … minutionem] minutionem sive additionem *C* 566 quantum] vero *add. C* ‖ minui … addi] addi vel minui *C* 568 sumi] *om. O* ‖ longioris] longe *O* 569 minuta] fuerint *C* 571 vel quarta] *om. O* 573–574 significat] signum *O* 574 tertiam] tertia *O* 575 additione] additionem *O* ‖ minutione] minutionem *O* 576 gradus] *om. O*

Sun according to the aforementioned principle. Next to seek the distance of the centre from the apogee [*ab auge*]. Next to correct the centre according to the firmament to know the distance of the centre from the apogee according to degrees on the firmament. Next to correct the anomaly of the small circle according to the centre and the degree of the firmament at which occurred the conjunction of the Sun and the planet, which is done by adding to the anomaly what was subtracted from the centre or subtracting from the anomaly what was added to the centre. Once these have been found, one must seek the distance between the planet and the centre according to degrees of the eccentre, that is, one must use the distance from the apogee in degrees of the epicycle to find its distance from the centre according to degrees of the eccentre and to make the distance according to the epicycle equal to the distance according to the eccentre. This is done [using] the tables, in which each number of degrees of separation from the apogee of the epicycle has ascribed to it a corresponding number of degrees of the distance from the centre according to the eccentre, which is found in the line for the degrees of the [correction of the] small circle.

Having found the distance from the centre according to the eccentre, one must seek the distance according to the firmament by making one equal to the other, which is found by adding the degrees of the nearer distance to the distance according to the eccentre or by subtracting the degrees of the farther distance from the distance according to the eccentre. For this addition or subtraction makes the distance according to the eccentre equal to the distance according to the firmament. The amount that must be subtracted or added is discerned by reference to the minutes of proportion that are ascribed to the [relevant] number of degrees. Their ratio with respect to 60 determines how much one must take of the degrees of the nearer or farther distance. This is to say, one takes a portion of the degrees that are found in the same line together with the degrees of the [correction of the] small circle that is as large as the part of 60 represented by the minutes of proportion, namely, depending on whether these minutes are one-half, or one-third, or one-quarter (and so on up to 60), one takes one-half, or one-third, or one-quarter of the degrees or minutes of the farther or nearer distance. And where you find 60 minutes of proportion, this indicates that you must take the whole amount; where there are 30, [you must take] one-half; where there are 20, one-third; where there are 15, one-quarter, and so on. And adding or subtracting this amount makes the degrees of the distance according to the

firmamentum. Illud enim queritur in omnibus directionibus ut in quoto gradu firmamenti sit planeta comperiamus.

Hec autem directio distantiarum secundum firmamentum dicitur ‘ultima directio’ partis, quia precessit prior per quam inventa fuit distantia planete a loco alto epicycli. Hec autem est per quam invenimus distantiam planete a puncto secundum gradus vel minuta firmamenti. Sequitur ut hec directio partis addatur vel minuatur puncto post directionem. Inde enim scietur *O* 105^{r} quantum distet Saturnus | ab auge secundum firmamentum. Addatur, si precedit punctum, minuatur, si sequitur punctum. Precedit vero punctum dum est infra VI signa a loco alto epicycli. Sequitur cum est ultra VI signa. Quod in figura superius posita liquido apparet. Patet enim quod cum est ab T ad X precedit punctum et cum est ab X ad T sequitur. Inde est quod hinc est addenda directio ad punctum, illinc minuenda a puncto. Sic itaque per illa duo precedentia comperta, scilicet quantum distet punctum ab auge secundum firmamentum et quantum distet planeta a puncto secundum firmamentum, colligitur quantum distet planeta ab auge secundum firmamentum. Est autem punctum bis directum cum hec directio ultima additur puncto vel subtrahitur a puncto.

Comperto quantum distet planeta ab auge secundum gradum firmamenti *C* 74^{v} | restat inquirere quantum distet ab Ariete, id est circulorum iunctura secundum firmamentum. Unde ultimo additur puncto bis directo locus altus, qui est quantum distat augis a iunctura. Comperto enim prius quantum distet ab auge ex precedentibus, sicut diximus, et hic addito quantum distet a iunctura, habetur quantum distet a iunctura secundum gradus firmamenti et sic invenitur in quantis signis vel gradibus vel minutis distet planeta secundum firmamentum a capite Arietis. Et hic est locus ipsius directus in firmamento. In quo esse hoc modo invenitur, quia semper querendus est locus planetarum secundum firmamentum tamquam magis necessarius loco secundum circulum suum, tam ad opus astronomie, quam ad operationem astrologie. Inventio tamen secundum circulum proprium precedit inventionem loci secundum firmamentum. Unde prius docemur invenire loca planetarum

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577 enim] *om. C* 578 gradu] gradus *O* ‖ sit planeta] planeta sit *C* ‖ comperiamus] comperimus *O* 579 distantiarum] differentiarum *C* 581 est] *om. O* 583 partis] partes *O* ‖ post directionem] prius directo *C* 585 punctum] *om. C* 586 dum est] deest *O* 587 superius] prius *C* ‖ liquido] inde(?) *O* 588 ad^{1}] in *O* 591 distet planeta] planeta distet *C* 593 bis] *om. O* 594 puncto] *om. O* ‖ a puncto] *om. C* 597 bis] brevi *O* 598 a iunctura] ab augis iunctura *C* ‖ prius] *om. C* 600 distet] distat *C* 601 quantis] quot *C* 602 est] *om. O* 607 firmamentum] *om. O* ‖ prius] *om. C*

eccentre equal with the degrees of the distance according to the firmament. For this is sought whenever the correction is computed so that we can ascertain the degree on the firmament in which the planet is located.

This correction of the distances according to the firmament is called the 'final correction' of the anomaly, because it was preceded earlier by the one used to find the distance between the planet and the apogee of the epicycle. This one, by contrast, is the one by which we find the distance between the planet and the centre according to degrees and minutes of the firmament. The next step is to add or subtract this [final] correction of the anomaly from the centre after it has been corrected. For this will yield knowledge of the distance of Saturn from the apogee according to the firmament. It must be added if it precedes the centre, subtracted, if it follows the centre. But it precedes the centre when it is less than 6 signs from the apogee of the epicycle. It follows it if it is more than 6 signs [from the apogee]. This becomes clear from the diagram placed above. For one can see that it precedes the centre when it is between T and X and follows it when between X and T. This is why the correction must be added to the centre in one case and subtracted from it in the other. In this manner, then, having ascertained the two preceding things, namely, the distance of the centre from the apogee according to the firmament and the distance of the planet from the centre according to the firmament, one derives the distance of the planet from the apogee according to the firmament. The centre, however, is twice-corrected once this final correction has been added to the centre or subtracted from it.

Having ascertained the distance of the planet from the apogee according to the degree on the firmament, it is left to inquire into its distance from Aries (i.e., from the equinoctial point) according to the firmament. The last step, therefore, is to add to the twice-corrected centre the apogee [*locus altus*], which is the distance between the apogee [*augis*] and the equinoctial point. For if one has previously ascertained the distance from the apogee, as we have said, and now adds to it [the apogee's] distance from the equinoctial point, one obtains the distance from the equinoctial point according to the firmament and thus finds the signs or degrees or minutes by which the planet is removed according to the firmament from the head of Aries. And there is its true position in the firmament. The reason it is found to be there according to this method is that one always has to seek the position of the planet according to the firmament, seeing as this is more necessary than the position according to its own circle, for the work of astronomy as much as for the practice of astrology. Finding the position according to its own circle nevertheless precedes finding the position according to the firmament. We therefore previously taught how to find the

secundum cursum mediatum, ut postmodum, sicut docuimus, inveniamus loca planetarum secundum firmamentum.

Aliter etiam dirigere poteris hoc modo. Fac directionem ultimam. Si et ipsa minuenda fuerit, et prima directio, que fuerit puncti, similiter fuerit minuenda, iunge eas et minue a cursu mediato primo. Et quod fuerit residuum post minutionem erit locus planete directus a numero secundum firmamentum. Si autem ambo addende fuerint, iunctas adde cursui mediato et habebis locum directum. Quod si altera addenda, altera minuenda fuerit, minues a maiore earum minorem. Et si maior fuerit addenda, residuum addes cursui mediato. Et si maior fuerit minuenda, minues residuum post *O* 105^{v} minutionem minoris a maiore ab ipso cursu mediato. | Et quod provenerit erit locus directus. Tantundem valet itaque sic dirigere quantum directionem ultimam addere vel minuere a puncto directo et deinde locum altum puncto bis directo addere.

Et ad evidentiam directionem quandam subiciemus. Cursus Solis, medius cursus puncti Saturni, medius locus altus minuendus a cursu medio, et cetera. ⟨...⟩

In predictis etiam id volumus attendi quod ordines signorum et graduum dupliciter accipiuntur. Accipiuntur enim pro distinctione remotionis ab auge et pro distinctione remotionis a loco alto epicycli. Quia secundum remotionem signorum et graduum ab auge requirimus directionem puncti. Et secundum remotionem a loco alto epicycli requirimus directionem graduum circuli parvi ad cognoscendum in quanta remotione a loco alto epicycli quanta sit distantia planete secundum excentricum a puncto. Et minuta proportionis sequutur directionem puncti secundum principium ab auge. Et minuta remotionis longioris vel propioris sequuntur gradus circuli parvi, sumende tamen secundum minuta proportionis. Habebis ergo duo initia, unum ab auge, alterum a loco alto epicycli. Et secundum initium augis sumitur directio puncti adiacens signis et gradibus ab auge supputatis. Et secundum alterum initium sumuntur gradus <directionis> circuli parvi adiacentes gradibus et signis a loco alto epicycli supputatis. In unaquaque enim linea

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609 loca planetarum] eadem *C* 610 fac directionem] facta directione *C* ‖ ultimam] ultima *C*; ulteriora *O* 612 quod] quo *O* 614 autem] vero *C* ‖ ambo] ambe *C* ‖ addende fuerint] fuerint addende *C* ‖ cursui mediato] mediato cursui *C* 615 locum] *om.* *C* ‖ altera] *om.* *O* 616 earum] eorum *O* 617 maior] minor *C* ‖ minues] minuas *O* 618 minutionem] *om.* *C* 619 valet itaque] itaque valet *C* 621 bis] brevi *O* 622 subiciemus] subiecimus *C*; subtraximus *O* ‖ *O*]

positions of the planets according to the mean motion, so that afterwards we can find the positions of the planets according to the firmament, as we have taught.

Another way by which you can compute the correction is this. Compute the final correction. If it must be subtracted and the first correction, which is that of the centre, must likewise be subtracted, you must join them together and subtract them from the mean motion. And what remains after the subtraction will be the true position of the planet according to the firmament. If they must both be added, however, add their sum to the mean motion and you will have the true motion. But if one must be added, the other subtracted, you will subtract the smaller from the greater. And if the greater must be added, you will add the remainder to the mean motion. And if the greater must be subtracted, you will subtract from the mean motion the remainder after subtracting the smaller from the greater. And the result will be the true position. Computing the correction in this way is, therefore, equivalent to adding or subtracting the final correction from the true centre and afterwards adding the apogee to the twice-corrected centre.

And to elucidate this point, we subjoin a specific correction: solar motion; mean motion of the centre of Saturn; mean apogee to be subtracted from the mean motion; etc. 〈…〉

One thing that we also wish to be borne in mind when it comes to the aforementioned things is that the columns for signs and degrees are taken in two different ways. For they are taken both to discern the distance from the apogee [*ab auge*] and to discern the distance from the apogee [*a loco alto*] of the epicycle. For we seek the correction of the centre according to the distance in signs and degrees from the apogee [*ab* auge]. And we use the distance from the apogee of the epicycle to seek the correction of the degrees of the small circle, so as to learn the distance of the planet from the centre according to the eccentre based on the distance from the apogee of the epicycle. And the minutes of proportion follow the corrected position of the centre with respect to the apogee. And the minutes of the farther or nearer distance follow the degrees of the [correction of the] small circle, though they are taken according to the minutes of proportion. You will accordingly have two beginnings, one from the apogee [*ab auge*], the other from the apogee [*a loco alto*] of the epicycle. And the apogee [*augis*] is the beginning for taking the correction of the centre, which is found adjacent to the signs and degrees counted from the apogee. And the other beginning is for taking the degrees of the correction of the small circle, which are found adjacent to the degrees and signs counted from the apogee of the epicycle. For written

ascribitur numerus graduum et minutorum pertinens ad illum numerum signorum et graduum cui ascribitur.

Et demonstrant numeri directionis puncti quanto minus vel plus perficiat punctum firmamenti quam excentrici, minus usque ad 3 signa ab auge supputata hinc et 3 illinc, plus supra. Et est hec demonstratio secundum quod recedit ab auge ad oppositum vel ab opposito ad augem, quia secundum hoc quod removetur ab auge vel per unum gradum, vel per plures, aut per unum vel per plura signa, habet nunc maiorem, nunc minorem directionem, nunc maximam, nunc nullam, interdum mediam, quantum ad firmamentum. Et gradus directionis circuli parvi demonstrant quantum sit remotus planeta a puncto suo per gradus excentrici secundum quod remotus est a loco alto epicycli plus vel minus. Et est 6 gradus et 31 minuta maxima additio secundum punctum. Et 6 gradus et 13 minuta maxima distantia planete a puncto secundum excentricum. Que tum maior est per 19 minuta secundum firmamentum, tum minor per tantundem, sicut prediximus.

Illud etiam colligitur ex predictis. Quia minutio est per 3 signa ab auge ante et totidem post, superscribitur merito minutis proportionis “minuit” donec pervenerit ad quadratum hinc et illinc, scilicet tria signa ante locum altum et post. A tribus signis in antea scribitur “crescit” usque ad 6 signa, quoniam per 6 signa sit crementum et per totidem minutio. Sed prius minutio, deinde crementum.

⟨III.iv⟩

Que diximus de Saturno eadem intelligantur de Iove et Marte, quoniam modus directionis idem, licet circulos epicyclos maiores habeant et plures gradus in directionibus et maiorem distantiam centrorum a centro firmamenti. Tanta autem erit distantia centri ad centrum firmamenti quanta fuerit maxima directio puncti cuiusque, utpote Saturni 6 gradus et 31 minuta, Iovis 5 ⟨gradus⟩ et 15 minuta, Martis 11 gradus et 24 minuta. Similiter in Venere et Mercurio. Tantum autem erit semidiameter epicycli quanta fuerit maxima directio circuli parvi, id est distantia planete a suo puncto secundum excentricum, utpote Saturni 6 gradus et 13 minuta, Iovis 11 gradus et 3 minuta, Martis 41 gradus et 10 minuta. Itaque habent centra sua distantiam a centro firmamenti, sed inequaliter et habent epicycli inequales, quas etiam inequalibus temporibus spaciis perficiunt. Nam Saturnus perficit epi-

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670 41] 4 *C* 670–671 distantiam] distantia *C*

in each line is a number of degrees and minutes that pertains to the number of signs and degrees next to which it is written.

And the numbers of the correction of the centre show how much more or less the centre completes with respect to the firmament than of the eccentre—less up to 3 signs counted from either side of the apogee, more if [the number of signs is] higher. And the reason this is based on the [planet's] departure from the apogee towards the perigee or from the perigee towards the apogee is that the distance from the apogee by one degree or several degrees or one or several signs makes it so that the correction with respect to the firmament is now greater, now smaller, now maximum, now zero, [and] sometimes mean. And the degrees of the correction of the small circle show the planet's distance from its centre according to degrees on the eccentre based on its distance from the apogee of the epicycle, [whether it be] more or less. And the greatest addition according to the centre is 6;31°. And the greatest distance of the planet from the centre according to the eccentre is 6;13°. It is sometimes 0;19° greater and sometimes [0;19°] smaller according to the firmament, as we have said before.

Another thing that can be gathered from what has said been before is this: since a subtraction is made [for distances] from the apogee that are up to 3 signs on either side, it is appropriate to write "decreases" above the minutes of proportion until one has reached quadrature on either side (i.e., 3 signs before and after the apogee). From 3 signs onwards one writes "increases" until [one reaches] 6 signs. For there is an increase that lasts 6 signs and a decrease that lasts for as many. But the decrease [comes] first, then the increase.

III.iv

What we have said about Saturn must also be understood about Jupiter and Mars, because the method of correction is the same, even though they have larger epicycles and more degrees in their corrections and a greater distance between their centres and the centre of the firmament. The distance between the centre and the centre of the firmament, however, will be as large as the maximum correction of the centre, which is 6;31° for Saturn, 5;15° for Jupiter, 11;24° for Mars. The same applies to Venus and Mercury. The radius of the epicycle, however, will be as large as the maximum correction of the small circle (i.e., the distance between the planet and its centre according to the eccentre), which is 6;13° for Saturn, 11;3° for Jupiter, 41;10° for Mars. Their centres accordingly [all] have a distance from the centre of the firmament, but an unequal one, and they have unequal-sized epicycles, which they also complete in unequal time spans. For Saturn completes the epicycle

cyclum 378 diebus et horis 2 et minuta hore 9, incipiens a loco alto epicycli, ubi semper coniungitur Soli. Et rediens ad ipsum predicto temporis spatio coniungitur item Soli. Predictum vero cursum sic colliges. Colliges cursum Solis tot diebus, horis et minutis et similiter cursum Saturni, quos videbis concurrere. Invenies enim Solem et Saturnum in nullo signo et in 12 gradibus et 39 minutis et 46 secundis distantes a loco in quo fuit precedens coniunctio. Saturnus enim movetur in excentrico singulis revolutionibus sui epicycli per 12 excentrici gradus et predictas minuta. Et tunc consequitur enim Sol et iterato ei coniungitur. Est autem coniunctio ista secundum cursus mediatos eorum.

Iteratur coniunctio Solis et Iovis in loco alto epicycli per dies 398 et horis 21 et 15 minuta hore, quia tanto temporis spatio toto epicycli perfectio redit ad locum altum. Et si collegeris cursum utriusque in tot diebus | *C* 75^{r} et horis et minutis invenies utrumque esse in uno signo et 3 gradibus et 9 minutis et 36 secundis, remotum scilicet tantum longe a loco in quo fuit coniunctio. Et si minueris cursum mediatum puncti Iovis in die uno a cursu medio Solis, scilicet 4 minuta et 59 secunda a 59 minutis et 8 secundis, reliquum, scilicet 54 minuta et 9 secunda, est cursus Iovis in epicyclo. Et cum duxeris has minuta et secunda in tempus predictum provenient 21600 minuta. Quas convertes in gradus per partitionem in 60 et habebis 360 gradus epicycli, quos perficit in spatio temporis predicto. Similiter in singulis planetis cum minueris cursum puncti sui diurnum a cursu Solis diurno, quod remanserit erit cursus planete illius in epicyclo diurnus. Et cum duxeris cursum in tempus quo perficit cursum suum et minuta que provenerint convertis in gradus per partitionem in 60, comperies 360 gradus epicycli, quos perficit in tempore invento.

Iteratur coniunctio Solis et Martis in loco alto epicycli sui diebus 779 et horis 22 et 22 minutis hore. Collecto enim cursu utriusque in hoc spatio temporis reperitur utrumque esse in uno signo et 18 gradibus et 44 minutis, et Martis in 6 secundis et Sol in 7 longe remotus a gradu excentrici in quo fuit precedens coniunctio. Et si minueris cursum diurnum puncti Martis, scilicet 31 minuta et 26 secunda, a cursu Solis diurno, reliquum erit 27 minuta et 42 secunda, quantum scilicet perficit in epicyclo suo in die. Quos minuta et secunda, cum duxeris in tempus predictum, provenient 21600 minuta, que faciunt 360 gradus.

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689 4] 40 *C* ‖ 59^1] 50 *C* 691 21600] 216000 *C* 700 22^2] 2 *C* 704 26] 21 *C* 706 21600] 21200 *C*

in 378 days, 2 hours, and 9 minutes of an hour, beginning from the apogee of the epicycle, where it is always in conjunction with the Sun. And when it returns to this [point] after the aforementioned period it is again in conjunction with the Sun. But you will gather the aforementioned motion in the following way. You will gather the motion of the Sun in this many days, hours, and minutes and also the motion of Saturn, which you will see coincide. For you will find that the Sun and Saturn are [both] 0s 12;39,46° from the place of the previous conjunction. For during each of its revolutions of the epicycle, Saturn moves on the eccentre by 12° of the eccentre and the aforementioned number of minutes. And then the Sun catches up and is once again united with it. This conjunction, however, is according to their mean motions.

The conjunction of the Sun and Jupiter recurs at the apogee of the epicycle every 398 days, 21 hours, and 15 minutes of an hour, because this is the period in which it completes the epicycle and returns to the apogee. And if you gather the motion of either of them in this many days, hours, and minutes, you will find that both are at 1s 3;9,36°, that is, this far removed from the place where the conjunction happened. And if you subtract the daily mean motion of Jupiter's centre from the mean motion of the Sun (i.e., 0;4,59° from 0;59,8°), the result (i.e., 0;54,9°) will be Jupiter's motion on the epicycle. And once you multiply these minutes and seconds by the aforementioned time, the result will be 21,600 minutes. You will convert these into degrees by dividing by 60 and you will have 360° of the epicycle, which it completes in the aforementioned period. The same applies to each of the [other] planets: if you subtract the motion of its centre from the daily motion of the Sun, the remainder will be the daily motion of this planet on the epicycle. And if you multiply the motion by the time in which it completes its motion and convert the resulting minutes into degrees by dividing by 60, you will find 360° of the epicycle, which it completes in the period that has been found.

The conjunction of the Sun and Mars recurs at the apogee of the epicycle every 779 days, 22 hours, and 22 minutes of an hour. For if one gathers the motion of either of them over this period, one will find that both are at 1s 18;44°, and that Mars is another 0;0,6° and the Sun another 0;0,7° removed from the degree on the eccentre in which the previous conjunction took place. And if you subtract the daily motion of Mars's centre (i.e., 0;31,26°) from the daily motion of the Sun, the remainder will be 0;27,42°, which is how much it completes on its epicycle per day. If you multiply these minutes and seconds by the aforementioned time, the result will be 21,000 minutes, which make 360°.

Iteratur coniuctio Solis et Veneris in loco alto epicycli vel in imo diebus 583 et 21 horis et 57 minutis hore. Quoniam si fuerit prius in loco alto coniunctio fit item in loco alto emenso predicto tempore. Et si fuerit in imo post tantum temporis iterabitur in imo. Et si fuerit in alto prius emenso medio tempore predicto fit in imo et emenso toto iterabitur in alto, et econverso. Et semper in loco alto erit Venus directa, in imo semper retrograda. Totum autem circulum perficit in tempore assignato. Et si cursum totum in tempore hoc assignato collegeris, invenies Venerem in nullo signo, gradu, minuto, secundo remotam esse a loco alto epicycli sui.

Iteratur coniunctio Solis cum Mercurio a loco alto in altum vel ab imo ad imum diebus 115 et horis 21 et 5 minutis hore. Facta autem coniunctione in alto fit post tempus medium predictum in imo. Et facta in imo fit post tempus medium predictum in alto. Et cum duxeris cursum partis diurnum, scilicet 3 gradus et 6 minuta et 24 secunda secundum quos scilicet percurrit Mercurius in epicyclo, in tempus predictum, provenient 360 gradus ipsius epicycli. Et sicut Venus, sic et Mercurius in loco alto semper est directus, in imo semper retrogradus. Et coniungitur Soli in loco alto et imo cum predicti, scilicet Saturnus, Iuppiter ⟨et Mars⟩ numquam coniungantur Soli nisi in locis altis epicycli. Et sicut illi ⟨…⟩

⟨III.V⟩

Planetarum stationes et retrogradationes considerantur secundum gradus firmamenti. Quia cum procedant motu suo ab anterioribus in posteriora signa firmamenti quandoque stant et morantur sub eodem gradu vel minuta firmamenti cum moveantur in epicyclis suis et tantundem uno die quantum alio. Utpote Saturnus cum fertur in epicyclo suo, quem superius annotavimus per distinctiones litterarum quatuor, ab T in V, tendit ab anterioribus in posteriora. Inde vero, id est ab V in Y, fertur in anteriora. Nec tamen statim est retrogradatio cum declinat ab V, sicut ostendemus. Quia cum corpus istius planete est in V et est in excentrico, sicut et punctum suum. Et tantundem movetur in posteriores gradus firmamenti quantum et punctum suum, quoniam et punctum suum, scilicet quod est epicycli existens semper in excentrico, semper procedit in posteriora, et totus epicyclus tantundem, et

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721 6] 2 *C* 733 t] v *C* 734 anteriora] posteriora *C*

The conjunction of the Sun and Venus recurs at the apogee of the epicycle or at the perigee every 583 days, 21 hours, and 57 minutes of an hour. For if there was previously a conjunction at the apogee, one will also happen at the apogee once the aforementioned period has been completed. And if it was at the perigee, it will recur at the perigee after this period. And if it was previously at the apogee, it happens at the perigee after half the aforementioned period has been completed and after the whole has been completed it will recur at the apogee, and vice versa. And at the apogee Venus will always be direct, at perigee always retrograde. But it completes the whole circle in the stated period. And if you gather the whole motion over this stated period, you will find that Venus is 0s 0;0,0° removed from the apogee of its epicycle.

The conjunction of the Sun and Mercury recurs at the apogee or at the perigee every 115 days, 21 hours, and 5 minutes of an hour. Where a conjunction has occurred at the apogee, it happens at the perigee after half the aforementioned period. And where it has occurred at the perigee, it happens at the apogee after half the aforementioned period. And once you multiply by the aforementioned period the daily motion in anomaly (i.e., by 3;6,24°), which [is the rate at which] Mercury moves on the epicycle, the result will be 360° of this epicycle. And just as is the case with Venus, Mercury is always direct when at apogee, always retrograde when at perigee. And it undergoes conjunction with the Sun at the apogee and at the perigee, whereas the aforementioned [planets] (i.e., Saturn, Jupiter, and Murs) only undergo conjunction with the Sun at the apogees of the epicycle. And just as these ⟨…⟩.

III.V

The stations and retrogradations of the planets are considered according to degrees on the firmament. For as they advance with their own motion from earlier towards later signs of the firmament, they sometimes stand still and remain below the same degree or minute on the firmament, whereas on their epicycles they [continue to] move in one day as much as in another. Saturn, for instance, while being carried on its epicycle, which we have marked above with four letters, aims from earlier towards later signs between T and V. But afterwards (i.e., between V and Y) it is carried towards earlier ones. And this retrogradation does not happen immediately once it descends from V, as we shall show. For when the body of this planet is at V it is also on the eccentre, just like its centre. And it then moves towards later degrees on the firmament at the same rate as its centre, because its centre (i.e., the one of the epicycle, which is always on the eccentre) always moves towards later ones, and the whole epicycle does so at the same rate, and the planet does

planeta existens in epicyclo tantundem, preter motum proprium quem facit in gradus epicycli.

Unde, si declinet planeta ab V non statim redit ad anteriores gradus firmamenti, quoniam fertur in posteriora motu puncti et epicycli, sed non redit ad anteriores excentrici. Et semper motu puncti et epicycli fertur in posteriora donec motu suo in epicyclo pacificetur motui puncti in posteriora, scilicet tantum feratur uno die versus X proprio motu in epicyclo quanta fertur motu puncti in posteriora die uno. Et nunc, cum ita adequantur motus in die uno ut neuter vincat alterum, est statio sub uno gradu firmamenti. Quoniam nec retrofertur per motum unum nec fertur in posteriora per motum alterum. Et inde incipit vincere planeta motu suo in epicyclo motum puncti sui. Utpote cum punctum Saturni moveatur in die per 2 minuta, cum corpus ipsius pervenerit ad V, ubi erit in excentrico sicut et punctum suum, fertur per motum puncti in die uno per 2 minuta. Inde declinans fertur in posteriora motu puncti non omnino per 2 minuta. Deinde per dimidum minus. Deinde per unum minutum minus. Deinde per minutum et dimidium minus. Deinde adequantur motus, cum tantundem die uno perfecerit excentrici in anteriora quantum punctum movetur in posteriora die uno. Et tandem vincit declinando postquam tantundem movebatur in die versus punctum et versus X quantum et fertur motu puncti.

Inde est quod non statim perfectis 90 gradibus, id est 3 signis, a loco alto epicycli retrogradatur. Perficiat potius supra 3 signa 25 gradus aut prope antequam retrogradetur quantum ad gradus firmamenti. In epicyclo tamen statim retrogradatur postquam declinaverit ab V. Et hec vocatur 'statio prima' ipsius cum tantundem perfecerit die uno in anteriora quantum fertur motu puncti et impulsu in posteriora. Et inde incipit retrogradatio usque dum pervenerit ad secundam stationem. Est vero secunda statio cum denuo moratur sub uno gradu neutro motu vincente alterum. Sed cum motus puncti vicerit dirigitur tendens et motu suo et motu puncti in posteriora.

Est autem retrogradatio donec tantundem distet a loco alto epicycli hinc quantum distabat illinc cum incepit retrogradatio. Unde inventa prima statione precipitur ut ad inventionem secunde minuatur prima statio a signis

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743–744 ad anteriores] ab anterioribus *C*   745 pacificetur] patificetur *C* ‖ posteriora] anteriora *C*   749 posteriora] anteriora *C*   757 tandem] tantundem *C*   758 movebatur] movebitur *C*

so at the same rate [by virtue of] being located on the epicycle, apart from its own motion that it performs along the degrees of the epicycle.

It follows that, if the planet descends from V, it does not immediately return to the earlier degrees on the firmament, because it is carried towards later ones by the motion of the centre and the epicycle, but does not return to the earlier ones on the eccentre. And by the motion of the centre and the epicycle it is always carried forward until it compensates for the forward motion of the centre with its motion on the epicycle, that is to say, its own motion carries it towards X on the epicycle by as much in a day as it is carried forward in a day by the motion of the centre. And at that point, since the daily motions become equal such that neither surpasses the other, [the planet] is stationary below one degree of the firmament. For it is neither carried backwards by one motion nor carried forward by the other. And thereupon the planet begins to surpass the motion of its centre with its own motion on the epicycle. For while the centre of Saturn moves 0;2° per day, once its body has arrived at V, where it will be located on the eccentre just like its centre, it is carried by the motion of the centre by 0;2° per day. [But] afterwards, as it descends, the rate by which it is carried forward is no longer entirely 0;2° per day. Next it is less by 0;0,30°, then by 0;1°, then by 0;1,30°. Next the motions are equal, because it goes backwards on the eccentre by as much as the centre goes forward in a day. And finally it takes overhand in descending, after it has moved towards the centre and towards X by the same daily rate at which it is carried by the motion of the centre.

This is the reason why it does not immediately become retrograde once 90° (i.e., 3 signs) from the apogee of the epicycle have been completed. It must instead complete 3s 25° or something close to it before it becomes retrograde with respect to the firmament. On the epiycle it nevertheless becomes retrograde immediately after it has [begun to] descend from V. And one uses 'first station' to refer to the moment when it goes backwards by as much in a day as it is carried forward by the motion and thrust of the centre. And from this point onwards it begins to be retrograde until it has arrived at the second station. The second station, however, occurs when it again remains below one degree with neither motion surpassing the other one. But as soon as the motion of the centre has taken overhand, it becomes direct and aims forward with both its own motion and the motion of the centre.

Its retrogradation, however, lasts until it is removed from the apogee of the epicycle on this side by as much as it was removed from it on the other side when the retrogradation began. It follows that once the first station has been found, the rule to find the second one is to subtract the first station

C 75$^{\text{v}}$

12. Et reliquum erit statio secunda. Quia quantum est prima statio a loco alto epicycli, tantundem est a secunda statione ad locum altum epicycli. Ut si sit prima statio 3 signa et 25 | gradus a loco alto epicycli, et locus altus erit remotus a secunda statione tantundem, et erit secunda statio in 8 signs et 5 gradibus, cum prima fuerit in 3 signis et 25 gradibus.

In tabulis autem directionum planetarum ibi notabis primam stationem ubi inveneris sequentem lineam tantum superare precedentem quantus est motus puncti in die uno. Et inde incipit retrogradatio. In quantum vero fuerit epicyclus brevior, erit retrogradatio diuturnior et post declinationem a quadrato loci alti epicycli velocior. Unde in Saturno longa retrogradatio, in Iove brevior et in Marte adhuc brevior. Quia citius vincitur motus puncti a motu planete in breviori epicycli, tardius vero in maiori. Et quia punctum minus movetur brevioris, citius vincitur punctum. Quod magis movetur in die, tardius vincitur. Ut punctum Saturni 2 minuta in die perficit, punctum Iovis 4 minuta, punctum Martis 31 minuta.

Super stationes autem inveniendas tabule composite indicant a quot signa epicycli incipiat retrogradatio. In quibus est prius ordo signorum et gradus incipientium ab auge. In alio ordine annotantur partes directe epicycli a quibus incipiunt retrogradationes. Que partes directe inde vocantur ‘stationes’, quoniam cum partes directe prime tales eveniant, stant planete secundum firmamentum. Futuri retrogradi. Designat itaque tabula stationum quante distantie ab auge quantum competat distantia a loco alto epicycli, ut ab ea incipiat retrogradatio. Et in singulis distantiis ab auge per unum gradus aut plures ascribuntur partes directe epicycli eis competentes a quibus debeat incipere retrogradatio. Utpote distantie Saturni ab auge per gradum unum ascribitur in eadem linea pars directa epicycli scilicet 3.2.44, tamquam si diceretur “cum distabit Saturnus de auge per gradum unum, si fuerit in tribus gradibus et 22 minuta et 44 secundis epicycli, erit tunc statio et inde incipiet retrogradatio.”

Si tamen, ut diximus, distans ab auge fuerit minus quam in 3 signis et cetera, non erit statio prima. Unde cum planeta fuerit distans ab auge per unum gradus vel plures, si inveneris partem directam minorem quam ea est que ascribitur tante distantie, agnosces planetam directum esse. Et si

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775 remotus] motus *C* 776 25] 5 *C* 786 martis] saturni *C* 801 tamen] tantum *C* 803 inveneris] minueris *C*

from 12 signs. And the remainder will be the second station, because the distance of the first station from the apogee of the epicycle corresponds to the distance of the second station from the apogee of the epicycle, such that, if the first station is 3s 25° from the apogee of the epicycle, and the apogee will have the same distance from the second station, then the second station will be at 8s 5°, since the first one was at 3s 25°.

But in the tables for the corrections of the planets, you will inscribe the first station where you find that the following line surpasses the preceding one by the amount of the daily motion of the centre. And the retrogradation begins at this point. The smaller the epicycle, however, the longer the retrogradation, and the sooner it will set in after [the planet begins to] descend from the point of quadrature with respect to the apogee of the epicycle. It follows that the retrogradation is long in the case of Saturn, shorter in the case of Jupiter, and even shorter in the case of Mars, because the motion of the centre is surpassed earlier if the planet moves on a smaller epicycle, later [if it moves] on a larger one. And since the centre of a smaller [epicycle] is slower, it will be surpassed sooner. A [centre] that moves by more in a day is surpassed later, inasmuch as the centre of Saturn completes 0;2° per day, the centre of Jupiter 0;4°, the centre of Mars 0;31°.

The tables that have been composed to find stations show the number of signs of the epicycle from which the retrogradation begins. The first column in these contains the signs and degrees beginning from the apogee. In the other column are written the true epicyclic anomalies at which the retrogradations begin. The reason these true anomalies are called 'stations' is that when these true anomalies first occur, the planets become stationary with respect to the firmament. They will be retrograde at the subsequent [degrees of anomaly]. The table of stations accordingly shows for each distance from the apogee the corresponding distance from the apogee of the epicycle at which the retrogradation begins. And next to the individual distances from the apogee, by one or more degrees, are written the corresponding true anomalies at which the retrogradation must begin, inasmuch as the value of the true anomaly of the epicycle that is written in the same line next to a 1°-distance of Saturn from the apogee is 3s 22;44°, which is tantamount to saying "when Saturn is 1° from the apogee, it will be stationary upon reaching 3s 22;44° of the epicycle and from this point onwards it will begin to be retrograde."

If, by contrast, its distance from the apogee is less than 3 signs etc., then, as we have said, the first station will not yet have occurred. If follows that if a planet is 1° or more removed from the apogee [and] you find a true anomaly that is less than the one written next to this distance, you will recognize that

inveneris partem directam illi que ascribitur parem esse, scias planetam in statione esse. Quod si maiorem quam primam eam inveneris et minorem secunda, scias planetam inter duas stationes esse et esse retrogradum. Et si parem inveneris partem directam secunde stationi, scias planetam in secunda futurum esse stationem. Si maiorem secunda, directum. Crescunt autem directe partes que sunt stationes prime et decrescunt secundum distantiam ab auge. Crescunt usque ad 6 signa. Deinde decrescunt. In quadratis equales et medie, sicut ipse tabule significant. Sed parum suscipiunt incrementum vel diminutionem.

⟨III.vi⟩

Singuli planete et luminariorum ignes habent circulos plures facientes motionum varietates. Habent enim singuli preter circulos in quibus sunt circulum similem circulo firmamenti, qui movet eos in annis 100 gradum unum circuli recti qui firmamentum concludit. Divisus in 12 partes equales, sicut et firmamentum. Et hii circuli equalem habent obliquitatem cum firmamento. Eadem vero est obliquitas firmamenti et zodiaci, id est vie Solis. Habent preterea Luna et planete circulos quosdam in quibus est eorum discursus, sicut Sol et zodiacum, scilicet viam qua feruntur. Et hii circuli sunt illis tamquam zodiacus, sed magis obliqui sunt zodiaco Solis et circulis quas habent ad simili⟨tudinem⟩ firmamenti. Et secant isti circuli magis obliqui alios minus obliquos bis. Et ille sectiones dicuntur ‘capita’ et ‘caude’ Lune et planetarum. Ubi vero secant illos, secant et zodiacum, utpote magis transversi versus meridiem et septemtrionem quam et zodiacus. Illa autem sectio dicitur ‘caput’ qua transiens Luna vel planeta accedit, ‘cauda’ autem transiens recedit.

Latitudo vero Lune est quantum distat a via Solis, scilicet zodiaci. Nulla autem cum capite vel cauda est, quia tunc est in sectione ⟨cum⟩ ipsa via Solis. Maxima quidem cum est in quadrato capitis vel caude, id est in medio, quia tunc magis distat a via Solis. ‘Dextra’ vero et ‘sinistra’ dicitur latitudo non quantum ad signa dextra vel sinistra, sed secundum zodiacum, quia cum citra est versus septemtrionem, dicitur ‘sinistra’, cum ultra, scilicet versus meridiem, est, dicitur ‘dextra’. Et ‘sinistra’ est eadem que et ‘septemtrionalis’,

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827 quam] qua *C*

it is direct. And if you find that the true anomaly is equal to the one written next to it, know that the planet is at its first station. But if [you find it] greater than the first and smaller than the second [station], know that the planet is between the two stations and [therefore] retrograde. And if you find the true anomaly to be equal to the second station, know that the planet will be at the second station. If [you find it] greater than the second [station], [know that it will be] direct. The true anomalies that [correspond to] the first stations increase according to the distance from the apogee. They increase up to 6 signs, then they decrease. They are level and of moderate size at quadratures, just as these tables indicate. Yet the decrease and increase they undergo is small.

III.vi

Each of the planets and luminaries has several circles that create variations in their motions. For apart from the circles on which they are located, each has a circle similar to the circle of the firmament, which in 100 years moves them by 1° of the circle that encloses the firmament. It is divided into 12 equal parts, just like the firmament. And these circles have the same obliquity as the firmament. The firmament, however, has the same obliquity as the zodiac, which is the path of the Sun. The Moon and the other planets have in addition certain circles on which they perform their motion, that is, a path on which they are carried, as is the case with the Sun and the zodiac. And these circles are like a zodiac unto them, but more oblique than the zodiac of the Sun and than their circles that are similar to the firmament. And these more oblique circles intersect the other less oblique ones at two points. And these points of intersection are called the heads and tails of the Moon and the planets. But where they intersect with them, the also intersect with the zodiac, inasmuch as they are more oblique towards the south and north than the zodiac. The point of intersection that is called the 'head' is the one the Moon or a planet passes as it ascends, [while] the 'tail' is the one that it passes as it descends.

The latitude of the Moon, however, is its distance from the path of the Sun (i.e., the zodiac). It is zero when it is at the head or tail, because it then intersects with the path of the Sun. It reaches its maximum when it is at quadrature from the head or tail (i.e., at the mid-point between them), because it is then at its greatest distance from the path of the Sun. But the latitude is called 'right' and 'left', not in the same sense as there are right and left signs, but according to the zodiac, because when it is on one side towards the north, it is called 'left', whereas when it is on the other side (i.e., towards the south), it is called 'right'. And 'left' is the same as 'northern', 'right' the same as

‘dextra’ que et ‘meridiana’. Similiter et planetarum. Proprie autem zodiacus est via Solis. Luna vero et planete extra zodiacum sunt quotiens egressi sunt viam Solis. Sed caput et cauda in via Solis sunt et in zodiaco esse dicuntur. Caput autem et cauda motu suo feruntur a posterioribus signis in anteriora, utpote ab Ariete in Pisces et sic in Aquarium.

Latitudo vero sinistra dicitur ‘superior’ quoniam sinistra nobis sunt superiora. Dextra inferior quoniam dexteriora sunt nobis inferiora. Et vocatur sinistra ‘apagon’, dextra ‘apagnon’. Cum vero est latitudo Lune in numero graduum ab uno ad 180, dicitur esse in ‘apagon’. Quoniam a capite incipit supputatio et est apagon a capite ad caudam. Cum vero est ultra 180 usque ad 360, dicitur esse dextra et in ‘apagnon’, quia est a cauda ad caput. Incipit supputatio latitudinis sicut supputatio longitudinis et numerantur similiter hic 12 partes equales latitudinis sicut ibi longitudinis. Dicitur autem latitudo ‘sinistra ascendens’ a capite ad 3 signa, id est gradus 90. ‘Sinistra’ vero ‘descendens’ inde usque ad caudam per alios 90 gradus. A cauda ‘dextra descendens’ usque ad alios 90. ‘Dextra ascendens’ usque ad ultimos 90 secundum completionem circuli.

Idem de latitudine Saturni, Iovis, Martis intelligendum. Hec supputatio signorum intelligatur secundum numerum graduum. In Marte siquidem est simul augis et latitudo maxima sinistra et remotio longior et apagon. Idem remotio propior et apagnon simul. Quod in reliquis non invenies.

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844 apagon] apanon *C* 845 apagon] apagum *C* 846 apagon] apagum *C* 856 apagon] apagnon *C*

'southern'. The same applies to the planets. The zodiac is the Sun's very own path, whereas the Moon and the planets are outside the zodiac whenever they depart from the path of the Sun. Yet the head and tail are within the path of the Sun and are said to be on the zodiac. The head and tail [of the Moon], however, are carried by their own motion from later towards earlier signs, such that they [go] from Aries to Pisces and from there to Aquarius.

The left latitude, however, is called 'superior' because things to the left are above us. The right one is [called] 'inferior' because things to the right are below us. And the left one is called 'apagon', the right one 'apagnon'. When the latitude of the Moon has a number of degrees between 1 and 180, it is said to be in the 'apagon'. For the count [of degrees] begins at the head and it is in the apagon when it is between the head and the tail. But when the [number of degrees] is higher than 180 up to 360, it is said to be in the 'apagnon', because it is between the tail and the head. The latitude of the Moon is reckoned in the same way as the longitude and one here counts 12 equal parts of latitude as one does elsewhere for the longitude. A latitude up to 3 signs (i.e., 90°) from the head is called 'left ascending'. From there to the tail through another 90° it is 'left descending'. From the tail through another 90° it is 'right descending'. For the final 90° until the circle is completed it is 'right ascending'.

The same must be understood about the latitude of Saturn, Jupiter, and Mars. This reckoning of signs must be understood according to the number of degrees. In the case of Mars there is in fact a coincidence between the apogee and the greatest left latitude and between the farther distance and the apagon. There is also a coincidence between the nearer distance and the apagnon. You will not find this to be the case with the other [planets].

Commentary

1.i

Ptolomeus opens by introducing us to two different ways of defining the solar year, tropical and sidereal. This distinction sets up the following discussions of precession and the resulting existence of two reference frames for measuring ecliptic longitudes (1.i–ii). Precession was not a topic that the astronomical sources available in Latin prior to the Arabic-to-Latin translations of the twelfth century had addressed with any degree of clarity, which may explain the length at which our text introduces some fundamental concepts.[1] In the early medieval *computus* tradition, a solar year was simply equal to the average Julian year of 365 ¼ days. While texts belonging to this tradition frequently distinguished the vernal equinox (commonly assigned to 21 March) from the Sun's entry into the sign of Aries (18 March), this disjunction was not conceptualized as a result of precession. If anything, it reflected an understanding of the signs of the zodiac as being tied to visible constellations, such that their boundaries were distinct from and independent of the equinoxes and solstices.[2]

In defining the tropical year, our text uses *iunctura circulorum* (l. 4), which literally denotes the 'intersection of the circles', or their 'joining-place', to express the concept of 'equinoctial point'. As already mentioned in § 3 (see p. 22), this expression echoes Ibn Ezra's מחברת שני הגלגלים ("intersection of the two circles").[3] Readers apparently were expected to understand that the two circles alluded to here are the ecliptic and celestial equator, whose points of intersection mark the equinoxes. In the text itself, the two circles are specified as those of the "firmament and the one above" (l. 4: *firmamenti et superioris*). If the firmament is the sphere of fixed stars, "the one above" (*superioris*) must be understood as a reference to the sphere above it, namely, the ninth sphere or *primum mobile*. In Ibn Ezra's LRT (p. 74, ll. 8–11), this sphere is described more clearly as the "highest circle" (*circulus altissimus*), also known as the "upright" one (*circulus rectus*), which is responsible for the diurnal revolution of the heavens and moves all the lower spheres along with it. *Ptolomeus* and the LRT are, hence, in implicit agreement that the material heavens consist of nine rather than just eight spheres. Indeed, this assumption was a straightforward way of accounting for the phenomenon of precession, which called for distinguishing the body responsible for the diurnal motion (the *primum mobile*) from the one moving the fixed stars in relation to the equinoxes (the sphere of fixed stars).[4]

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[1] The most explicit references to precession in pre-twelfth-century Latin literature are probably those in Macrobius, *Commentarii in Somnium Scipionis* 1.17.16–17, 2.11.9 (ed. Armisen-Marchetti 2001–2003: i. 97; ii. 49–50). See also Obrist 2019: 125.

[2] For more on this early medieval background, see Nothaft 2017c: 251–261.

[3] *Sefer ha-Ṭeʿamim* I, § 2.12:3, 6 (ed. Sela 2007: 50).

At the start of our text, the idea of measuring the solar year according to the Sun's return to one of the equinoctial points is attributed to Ptolemy as well as many other "sages" (l. 3: *multi sapientum*). This statement is consistent with the beginning of the third book of Ptolemy's *Almagest*, where he indeed argues in favour of a tropical year and subsequently proposes for it a length of 365;14,48d.[5] Since this is equivalent to 365d 5;55,12h, it appears extremely likely that the value 365d 5;50,12h given in MS *C* was disfigured by a scribal mistake and ought to be emended. The information provided in *Ptolomeus*'s opening paragraph is, in fact, mirrored in Abraham Ibn Ezra's LRT, which likewise presents Ptolemy as an advocate of a tropical definition of the year (p. 80, ll. 10–13; p. 84, ll. 9–14), attributing to him a year length with a rotational excess of 88;48° (p. 82, ll. 17–25). Converted into units of time, this excess corresponds to the expected 5;55,12h.[6]

The claim that the ancient Indians championed a sidereal year and found its length to be 365 ¼ + 120 days (ll. 12–15) is again a recurring feature of Ibn Ezra's writings in Hebrew as well as Latin.[7] In the LRT (p. 75, ll. 1–5), it is augmented by the remark that the same solar year underlies the astronomical tables of al-Khwārizmī (*Alcaurezmi*), Ibn al-Ṣaffār (*Abnezafar*), and Maslama (*Mezlame*). Al-Khwārizmī (d. *c.* 850) is known as the originator of a ninth-century adaptation of the *Zīj al-Sindhind*, which, as the name itself suggests, relied on Indian models and parameters. The Andalusian astronomer Maslama al-Majrīṭī (d. 1007/8) and his student Ibn al-Ṣaffār (d. 1035) were both responsible for later revisions of al-Khwārizmī's *zīj*.[8] Ibn Ezra's familiarity with the work and its parameters is evident from numerous references and allusions in the LRT as well as from his Hebrew translation of a commentary on the same tables by Ibn al-Muthannā.[9] One of the tables in the preserved Latin version of the *zīj* (Maslama's recension) makes the year last 365d 6;12,9h = 365;15,30,22,30d, with a rotational excess of 93;2,15°.[10] If these figures are respectively rounded to 365d 6;12h =365;15,30d and 93°, the result is equivalent to the year length of 365 ¼ + 120 days that Ibn Ezra was wont to attribute to the Indians.[11]

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[4] On the background, see Obrist 2019, where the relevant passage in Ibn Ezra's LRT is discussed on pp. 131–133.

[5] See Ptolemy, *Almagest* 3.1 (trans. Toomer 1998: 131–140); Pedersen (Olaf) 2011: 131–132.

[6] For other references to Ptolemy's tropical year in Ibn Ezra's works, see *Sefer ha-Ṭeʿamim* I, § 2.12:5 (ed. and trans. Sela 2007: 50–51); *Sefer ha-Moladot*, IV.1:6 (ed. and trans. Sela 2014: 182–183); *Sefer ha-ʿOlam* I, § 17:1 (ed. and trans. Sela 2010: 62–63); *ʿOlam* III, § 6.1:4, 3:8 (pp. 250–251). Further passages are noted in Sela 2014: 343–344.

[7] *Sefer ha-Ṭeʿamim* I, § 2.12:6 (ed. and trans. Sela 2007: 50–51); *Sefer ha-Ṭeʿamim* II, § 8.3:1 (ed. Sela 2007: 250–251); *Sefer ha-Moladot*, IV.1:1 (ed. and trans. Sela 2014: 182–183); *ʿOlam* III, § 6.1:2 (p. 250). Further passages are noted in Sela 2014: 341, and printed in Sela 2003: 373–374, 376–377 (from the commentary on Leviticus 25:9 and *Sefer ha-ʿIbbur*).

[8] On the *zīj* of al-Khwārizmī and its different versions, see Mercier 1987: 88–102; Pingree 1976: 151–169; 1996; King and Samsó 2001: 31–35, 56–57; van Dalen 2018; Chabás 2019: 34–39; Samsó 2020: 688–702.

An important feature that unites *Ptolomeus* and the LRT, but sets these texts apart from Ibn Ezra's other writings, is the way in which they draw a clean line of separation between the astronomical applications of the tropical reference frame and the astrological uses of the sidereal one.[12] According to *Ptolomeus*, the tropical year is strictly relevant to astronomical computations (ll. 8–11), whereas astrologers base their judgments and talismans (*imagines*) on a sidereal definition of the solar year (ll. 16–18). The text in *C* states that one of these astrologers' habits is to pay attention to the "conjunction of the fixed stars with the fixed stars" (*coniunctionem stellarum fixarum cum fixis stellis*), which is nonsensical. In emending this passage to "conjunction of the planets with the fixed stars" (ll. 17–18: *coniunctionem planetarum cum fixis stellis*), I draw on a parallel passage in *Inter omnes recte philosophantes*, which is in part a paraphrase of *Ptolomeus* (see p. 23): *Indi* […] *animum ad iuditia vertunt, quorum omnis ratio et universus ordo* ***a coniunctione planetarum cum stellis fixis*** *proficiscitur*.[13]

As examples of astrologers who champion the sidereal year, our text mentions *Thebit Christianus* et *Abuchalich Ebetine* (ll. 18–19). While I have not able to identify the latter, the former is clearly Thābit ibn Qurra (d. 901), whose known writings include a work on astronomical talismans (*De imaginibus*).[14] *Ptolomeus*'s incorrect labelling of this author, who was a member of the Sabian religion, as a Christian (*Thebit Christianus*) is mirrored in the LRT, where he appears as 'the greatest of the Christian philosophers' (p. 76, ll. 8–9: *Tebit Bencore christianorum summus philosophorum*).

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[9] Ibn al-Muthannā, *Commentary on the Astronomical Tables of al-Khwārizmī*, trans. Abraham Ibn Ezra (trans. Goldstein 1967: 148–182).

[10] Suter 1914: 230 (Tab. 115); Neugebauer 1962b: 131–132; van Dalen 2018: 113.

[11] Pingree 1976: 154; Samsó 2012: 179.

[12] See on this point Nothaft 2021b: 66–72. For relevant passages in the LRT, see p. 83, l. 24–p. 85, l. 15; p. 94, ll. 4–7.

[13] MS Parma, Biblioteca Palatina, 418–420, fol. 423^v.

[14] Burnett 2007.

Having introduced the two types of solar year, *Ptolomeus* next indicates the root cause behind their divergence, which is the proper motion of the fixed stars (ll. 20–24). Our author expressly accepts that the solar apogee moves at the same rate as the fixed stars (l. 23), which contrasts with Ptolemy's original position of treating the apogee as tropically fixed. The insight that the apogee undergoes precession can be traced back to the Arabic treatise *On the Solar Year*, which was written in Baghdad in the second quarter of the ninth century (after 832).[15] A reference in the LRT (p. 79, ll. 23–24) indicates that Ibn Ezra was familiar with this work and its common (but mistaken) attribution to Thābit.

Ptolemy's original fixed tropical longitude for the solar apogee was 65;30°,[16] which is 1;30° ahead of the value mentioned in the preserved text of *Ptolomeus* (ll. 25–26: *in 4 gradibus Geminorum*). The text in *C* further states that precession has moved the longitude of the solar apogee forward to 18° Gemini plus some minutes of arc (ll. 26–27), which is at odds with the apogeal longitude of 27° Gemini given later in pt. II (l. 156) and III (ll. 35–45, 77, 104–112). The way towards an emendation is shown by a parallel passage in the LRT, which contrasts Ptolemy's apogee in the 6th degree of Gemini (p. 77, ll. 19–20; cf. p. 91, ll. 25–26) with the values that Islamic sources give for the present year AD 1154. According to the text printed by Millás (p. 78, ll. 2–5), these sources agreed on putting the apogee at 17° Gemini with an addition of some minutes (i.e., within the 18th degree): *Omnes autem magistri probationum* [...] *concordant in hoc quod in eodem anno proterierat* [!] *17 gradum et aliquod minuta*. A look at the variants recorded in Millás's edition indicates that the number *17* originated as an error for *27*, as found in a twelfth-century Oxford copy of the LRT.[17] Besides being an astronomically plausible apogeal position for the mid-twelfth century, the value of 27° Gemini is also attested in some of Ibn Ezra's Hebrew works.[18]

The text in *C* goes on to state that the position of Regulus (α Leo) increased from the 3rd degree of Leo at the time of Ptolemy to a present longitude in the 6th degree Leo (ll. 27–28). Ptolemy's star catalogue puts Regulus at 122;30° and thus confirms the first half of this statement.[19] Yet the implied increase of only 3° between Ptolemy and the mid-twelfth century is plainly to small and calls for another emendation. This is easily provided for by the parallel remark in the LRT, which puts the present-day position of Regulus in the 18th degree of Leo (p. 82, ll. 4–6; p. 84, ll. 18). The placement of this star somewhere in the 18th degree of Leo, or rounded to 18° Leo, also features in several other texts in Ibn Ezra's Hebrew and Latin corpus.[20] One may, therefore, speculate that in the case of *C* the number *18* was somehow transposed from designating the present location of Regulus to the present location of the solar apogee, where it replaced the correct reading of *27*.

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[15] See Morelon 1996: 26–31. An edition of the Arabic text and a French translation were published in Morelon 1987: 27–67. For a commented English translation, see Neugebauer 1962a: 265–289.

[16] Ptolemy, *Almagest* 3.4 (trans. Toomer 1998: 155); Pedersen (Olaf) 2011: 135, 147–149.

[17] Oxford, Bodleian Library, Digby 40, fol. 53^{v}.

[18] *Reshit Ḥokhmah* 2.3:35 (ed. and trans. Sela 2017: 76–77); Ibn al-Muthannā, *Commentary on the Astronomical Tables of al-Khwārizmī*, trans. Abraham Ibn Ezra (trans. Goldstein 1967: 150).

[19] Ptolemy, *Almagest* 7.5 (trans. Toomer 1998: 367).

Yet more evidence of corruption in *C*'s numbers is contained in the remarks addressing the present-day gap between tropical 0° Aries and the sidereal beginning of this sign. Once sufficiently emended, the text appears to state that the tropical sign entry precedes the sidereal one by 9° (ll. 30–37). There is still an apparent conflict with the subsequent claim that the vernal point is currently at 22° Pisces of the sidereal zodiac (ll. 37–38). It can be resolved by interpreting *22 gradus Piscium* literally as the "22nd degree of Pisces," which would be 9° behind the '1st degree of Aries'. In either case, this gap is clearly more modest than the increase in stellar longitudes since Ptolemy's day, which the text previously gave as *c.* 15°, citing the example of Regulus. It follows by implication that the moment when the sidereal and tropical beginnings of Aries were in alignment with each other occurred centuries after Ptolemy. Our text merely states that the coincidence in question happened "in ancient times" (ll. 30–31: *initium … signi Arietis antiquitus fuisse in ipsa circulorum iunctura*), which is not strictly inconsistent with a post-Ptolemaic date. However, the further assertion that the equinox became known as the 'head of Aries' on account of this ancient coincidence (l. 32) would seem to imply that it preceded Ptolemy's introduction of a tropical zodiac.

Given the importance of precession to the discussion in I.i and the following sections, it is curious that the text as we have it never spells out its actual rate. That the Tables of Pisa originally came with a set of precession tables is suggested by a passage in the *Tractatus magistri Habrahe de tabulis planetarum*, although this source makes no mention of the underlying parameter.[21] A relevant value is instead recorded in a canon that accompanies the Pisan tables in manuscript *K* (see p. 165), which states that the planetary apogees move at an annual rate of 0;0,51°.[22] *Artis cuiuslibet consummatio*, a work influenced by *Ptolomeus* (see § 4), affirms this precise rate of precession in a chapter incorporating a list of apogeal values for AD 1193.[23] The same apogeal longitudes are written beside the mean-motion tables in manuscript O_2 (fols. 30^r, 32^r–34^r), confirming their connection with the Tables of Pisa.[24] Precession tables constructed on the basis of a rate of 0;0,51°/y appear in several Latin manuscripts of the thirteenth century, albeit not as part of the Pisan tables. They are usually accompanied by a set of apogeal values for AD 1100, which do not show a constant difference to those in O_2 and *Artis cuiuslibet consummatio*.[25]

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[20] See *Reshit Ḥokhmah* 2.5:43 (ed. and trans. Sela 2017: 92–93); *Sefer ha-Ṭeʿamim* I, § 1.2:3 (ed. and trans. Sela 2007: 30–31); *Liber nativitatum* II.i.7.(9) (ed. and trans. Sela 2019: 112–113); commentary on Amos 5:8 (Sela 2003: 372–373); Sela 2017: 346; Goldstein 1985: 193.

[21] *L*, fol. 56ᵛ: "Si anni ad quos operaris 1149 excedunt non curatis mensibus intra cum differentia eorum annorum in tabulas motus fixarum. Et quod ibi invenies adde loco alto planete."

The hypothesis that these precession tables originated as part of the Tables of Pisa is strengthened by Ibn Ezra's extant writings on astrology and astrolabe, in which he repeatedly endorses a precession rate of 1° per 70 years (= 0;0,51…°/d).[26] The LRT, while not taking an explicit stance on the matter, attributes this rate of 1°/70y to al-Ṣūfī (p. 78, ll. 9–10), whose parameters provided the basis for the Tables of Pisa. In *ʿOlam* III (§ 6.3:13, p. 251), the same value is linked to a larger group of unidentified Islamic astronomers, the *magistri probationum*, who accepted it alongside a tropical year with a rotational excess of 87;15°.[27] This corresponds to a year length of 365d 5;49h, as used in the Tables of Pisa (see p. 9). Another passage in *ʿOlam* III (§ 7.1:7, p. 252) allows us to infer that precession tables constructed on the basis of 0;0,51°/d and the aforementioned list of apogeal values for AD 1100 also accompanied the Tables of Winchester, an adaptation of the Tables of Pisa presumably made by Ibn Ezra himself.[28] In light of all this evidence, it seems easily explicable why Henry Bate, one of Ibn Ezra's most prolific Latin translators, used the same precession rate when casting his Tables of Mechelen (*c.* 1280), which were modelled on the Tables of Pisa.[29]

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[22] *K*, fol. 192^{vb}: "A medio motu planete subtrahe augem eius. Qui aux crescit omni anno 51 secundis."

[23] *Artis cuiuslibet consummatio* 2.26 (ed. Victor 1979: 284): "Et si vis scire ubi erunt post multos annos, pro singulis annis distantie addes 51 secunda. Si vis scire ubi fuerunt ante multos annos, pro singulis annis demes ab altis locis prefata 51 secunda."

[24] *Artis cuiuslibet consummatio* 2.26 (ed. Victor 1979: 282). The apogeal values in O_2 are the same as those in witness *H* recorded in Victor's edition for all planets except Saturn, where the discrepancy is minor (250;42° according to O_2, 250;47° according to *H*).

[25] See tables DB21 in Pedersen (Fritz) 2002: iii. 1226–1227. The known witnesses are MSS Cambridge, University Library, Kk.1.1, fol. 171^v (s. $\text{XIII}^{1/2}$); Cambridge, University Library, Mm.3.11, fol. 104^v (s. XIV); Erfurt, Universitätsbibliothek, Dep. Erf. CA 4° 364, fol. 102^v (s. XIII/XIV); Firenze, Biblioteca Nazionale Centrale, Conv. soppr. J.V.6, fol. 83^v (s. XIII); Oxford, Bodleian Library, Savile 22 (s. XIII^{med}), fols. 76^r (apogees), 79^r (precession).

[26] See *Sefer ha-Ṭeʿamim* I, § 2.12:10 (ed. and trans. Sela 2007: 50–51); *Sefer ha-Ṭeʿamim* II, § 1.2:4 (ed. and trans. Sela 2007: 182–183); *Liber nativitatum* II.i.7:2 (ed. and trans. Sela 2019: 110–111); *De astrolabio* (ed. Millás Vallicrosa 1940: 20); *De mundo vel seculo*, trans. Henry Bate (ed. Steel 2019: 261, ll. 515–517); pseudo-John of Seville (= Abraham Ibn Ezra?), *Epitome totius astrologiae* 2.7 (ed. 1548, sig. $K1^r$); and the further passages noted by Sela 2007: 137; 2019: 211. On the influence of this parameter in Latin Europe, see Nothaft 2017b: 220, 223–224, 226. On its origins in Islamic astronomy, see Mozaffari 2016: 303–306.

[27] See my remarks in Sela, Steel, Nothaft, Juste, and Burnett 2020: 208.

I.ii

Our text continues to be paralleled closely by the LRT (p. 84, ll. 9–24) as well as by *ʿOlam* III (§ 6.4:1–3, pp. 251–252) when it reports how Ptolemy and the Indians devised two diverging reference frames for assigning ecliptic longitudes, in accordance with their respective definitions of the year (ll. 45–70). According to the account in *Ptolomeus*, the Indians not only invented the sidereal reference frame, but discovered the underlying constellations and assigned them their names. From these constellations, they later abstracted twelve zodiacal signs of 30° each, whose boundaries were not coterminous with those of the corresponding constellations (ll. 55–66). The author mentions the example of Aries, whose constellation, according to the reading preserved in *C*, begins in the 12th degree of the sidereal sign bearing the same name (l. 62). A similar statement in the LRT gives the distance between the horns of (the constellation of) Aries and the beginning of the sign of Aries as 22° in the tropical sign (p. 84, ll. 17–18) and as 9;25° in the sidereal sign defined by the Indians (p. 84, ll. 22–24). Ptolemy's star catalogue has the frontmost star of the constellation of Aries at 6;40°.[30] Assuming, as before, a precessional increase of *c.* 15° between Ptolemy and the present (see p. 140), this would put the same star at 21;40°, in approximate agreement with one of the statements in the LRT (p. 84, ll. 17–18: *et distant eius cornua ab initio illius distinctionis 22 gradus*).

In line with their assertion that astrological judgments are or must be based on a sideral zodiac, both *Ptolomeus* and the LRT remind their readers of the conversions that become necessary when astrological forecasts are made from astronomical data. The text in *C* here adjusts its earlier talk of a 9°-gap between reference frames to now prescribing a subtraction of 8°, the assumption being that tropical 0° Aries = sideral 22° Pisces (ll. 72–77). The LRT specifically recommends this subtraction of 8° to those who seek to compute planetary longitudes by means of the Tables of Pisa (p. 89, ll. 16–19), whereas *Ptolomeus* merely speaks of certain *tabulas experimenti* (ll. 75–76). This expression finds a parallel in Ibn Ezra's *Sefer ha-Ṭeʿamim*, where he mentions the "tables of the scholars who rely on experience," again in the context of prescribing a subtraction of 8° for astrological purposes.[31] It is also reminiscent of the expression *tabule probationum* used in the LRT (p. 76, l. 7), which appears to be a calque on the *zīj al-mumtaḥan* ("verified tables") created by Yaḥyā ibn Abī Manṣūr (d. 830).[32] The astronomers who contributed to these or similar tables were known as *aṣḥāb al-mumtaḥan* ("authors of the verified tables"), which the LRT renders as *magistri probationum*. However, in the context of the LRT this expression has a greater scope of reference, as it equally applies to all other Eastern Arabic astronomers who, like al-Ṣūfī, constructed their tables with a tropical reference frame and endorsed a fixed tropical year and linear rate of precession.[33]

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[28] See my remarks in Sela, Steel, Nothaft, Juste, and Burnett 2020: 215.

[29] See Nothaft 2018a: 287–290.

[30] Ptolemy, *Almagest* 7.5 (trans. Toomer 1998: 360).

It should be noted that the mentioned passage in the *Sefer ha-Ṭeʿamim* only tells readers to subtract 8° from their tropical longitudes in case they wish to base their astrological judgments on an Indian tradition that distinguishes 'bright' and 'dark' degrees as well as degrees on a sidereal zodiac that are known as 'pits'.[34] *Ptolomeus*, by contrast, speaks of the "greater part of judgments" (l. 73: *pars maior iuditiorum*) and indicates that the subtraction affects fundamental parameters such as the degree of the ascendant and the cusps of the houses (ll. 74–75). Our text also goes beyond the LRT in discussing how to convert between reference frames when using an astrolabe. Its account is rather misleading, insofar as it tells us to work with the sideral degree of the Sun when computing astrologically relevant parameters (ll. 77–81). Since the zodiac inscribed on an astrolabe's rete is always tropical, calculations involving the Sun's position must necessarily use the tropical position or run the risk of error. The difference in reference frames would instead have to be factored in at the end of the calculation, for instance by reducing the resulting ascendant degree by 8°.[35]

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[31] *Sefer ha-Ṭeʿamim* I, § 2.12:14 (ed. and trans. Sela 2007: 52–53).

[32] See van Dalen 2004.

[33] See Samsó 2012: 193–194; 2020: 823–824.

[34] *Sefer ha-Ṭeʿamim* I, § 2.12:14 (ed. and trans. Sela 2007: 52–53); *Sefer ha-Ṭeʿamim* II, § 8.7:4–6 (ed. and trans. Sela 2007: 254–255).

[35] This is indeed how some twelfth-century Latin texts seek to make the astrolabe applicable to astrological purposes. See Nothaft 2021b: 53, 58–59, 67–68.

I.iii

The average Julian year of 365 ¼ days lies somewhere between the two lengths of the solar year discussed so far, with the result that neither of the two corresponding reference frames remain fixed with respect to the calendar. Tropical sign-entries will gradually move towards earlier calendrical dates over time, whereas the sidereal sign-entries shift in the opposite direction. According to *Ptolomeus*, the sidereal entry into Aries as predicted by the Indians has moved by nine days between Ptolemy and the present day, from 14 March to 23 March. In the case of the tropical entry, the dates are exactly reversed (ll. 84–89).

The author presumably derived his ‘Indian’ dates from the *zīj* of al-Khwārizmī (see pp. 137–138), which predicts sign-entries into Aries on 14 March and 23 March for the years AD 140 (Ptolemy) and 1145 (present). His claim that the Sun currently enters tropical Aries on 14 March is consistent with the examples given later in pt. II (ll. 41–42, 144, 193–195, 211–212) as well as with the Tables of Pisa. Yet the vernal equinox of AD 140 fell on 22 March according to Ptolemy’s own observations,[36] while the Tables of Pisa put the same equinox on 21 March.[37] An equinox on 22 March in Ptolemy’s time would imply a gap of eight days with respect to the ‘Indian’ date, which is indeed what is asserted in Ibn Ezra’s *ʿOlam* III (§ 6.2:6, pp. 250–251). The LRT instead seems to accept 21 March, seeing as it reduces the ancient gap between Ptolemy and the Indians to seven days (p. 81, ll. 20–23; p. 86, ll. 11–12). That said, both the LRT (p. 81, ll. 23–26) and *ʿOlam* III (§ 6.2:8, p. 251) agree with *Ptolomeus* that the gap between sign-entries has reached nine days in present times.[38]

Ptolomeus’s statements about the relevant dates in Ptolemy’s day and the present imply that the equinoxes shift at an approximate rate of 9 days in 1000 years, from 23 March in *c.* AD 140 to 14 March in *c.* AD 1140. In explaining this calendrical regression, the author nevertheless continues to rely on the Ptolemaic estimate for the length of the tropical year, which implies a much slower shift of 1d/300y or 3 1/3 days in 1000 years (ll. 90–116). He accordingly claims that the equinoctial date regressed by merely two days between Ptolemy and the time of Thābit and al-Battānī, who were active in the ninth century (ll. 117–121). Assuming a Ptolemaic equinox of 23 March, the equinoctial date in the time of Thābit and al-Battānī should therefore have been 21 March. Rather than mentioning this date, the text in *C* transitions from 23 March in Ptolemy's time to *et in eorum in 14* (ll. 120–121), hence suggesting a shift by nine days between Ptolemy and Thābit/al-Battānī. It seems possible that the text is here affected by an omission, which would explain the awkward transition to the statements that follow. These suddenly re-introduce the Indians, invoking a hypothetical scenario accordingt to which the only difference between Ptolemy and these Indians is calendrical, such that 14 March and 23 March are really the same day in two different systems of reckoning (ll. 122–124).

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[36] Ptolemy, *Almagest* 3.1 (trans. Toomer 1998: 138); Pedersen (Olaf) 2011: 128, 421.

[37] Assuming an initial radix of 344;30,20° on 1 March 1030 (see *Ptolomeus*, pt. II.iv, ll. 425–426) and a positive shift of solar longitude of 0;9° per 20 years (I.v, ll. 248–256), the mean longitude on 21 March 140 was *c.* 358;2,11°. A true longitude of 0° will be reached on the same date, assuming that the apogee is in mid-Gemini.

[38] This also agrees roughly with the 9°-gap between sidereal and tropical longitudes mentioned in *Sefer ha-ʿOlam* I, § 11:3 (ed. and trans. Sela 2010: 58–59); *Sefer ha-ʿOlam* II, § 45:4 (ed. and trans. Sela 2010: 184–185), and the 9 ½° in Ibn al-Muthannā, *Commentary on the Astronomical Tables of al-Khwārizmī*, trans. Abraham Ibn Ezra (trans. Goldstein 1967: 149, ll. 31–32).

The author continues by mentioning *Symon et Assimon*, who made the tropical year longer than the Julian year, asserting a length of 365 ¼ + 1/76 days (ll. 125–128). This is a reference to the ancient Athenian astronomers Meton and Euctemon, who are credited with the same year length in the *Almagest*.[39] As a further aside, the author brings up Azarquiel (Ibn al-Zarqālluh, d. 1100) and his proposal of a third variant of the solar year, namely, the anomalistic year, the existence of which followed from Azarquiel's assumption that the solar apogee moves at a rate greater than precession. We are expressly told that this is not in fact the case (ll. 128–130). The author's introduction and immediate rejection of Azarquiel's anomalistic year finds a clear parallel in the LRT, where this notion is discussed at greater length (p. 79, l. 21–p. 80, l. 10).

I.iv

Having clarified the idea of two different reference frames, tropical and sidereal, our text returns to the root cause of this dichotomy, which is a slow motion performed by the sphere of fixed stars. A fundamental theoretical choice to be made in this area was between a simple linear model of precession, as postulated by Ptolemy and his successors, and one that treated the rate of precession as a variable quantity. *Ptolomeus* briefly outlines two models of the latter type, which are here both presented as Indian inventions. The languague in this passage is particularly obscure and sometimes confusing, as when the text suggests that the firmament periodically changes some undefined "point" (*punctum suum*), such that its parts are sometimes nearer and sometimes farther from the "earth" (*terra*) (ll. 135–139). This must be presumably be understood as describing a secular change in the obliquity of the ecliptic and the corresponding elevation of the pole star, as implied by the Islamic theory known as the 'access and recess' of the eighth sphere. As is alluded to in our text, the theory in question describes an oscillating back-and-forth motion that results from the slow revolution of two points on the surface of the sphere of fixed stars, the heads of Aries and Libra, around centres that are located on the celestial equator (ll. 139–141).[40]

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[39] Ptolemy, *Almagest* 3.1 (trans. Toomer 1998: 139).

An early variant of this theory exerted a significant influence on medieval Latin astronomy owing to its inclusion in the so-called Toledan Tables, which dominated astronomical practice during the twelfth and thirteenth centuries.[41] *Ptolomeus* not only alludes to the access-and-recess theory but spells out one of its more important consequences, which is that the length of the tropical year varies over time, whereas the sideral year remains fixed (ll. 141–145). The fact that the theory thus privileges a sidereal reference frame, as used in the Toledan Tables, may explain why our text associates it with the Indians. A parallel passage, with the same attribution to the Indians, occurs in the LRT (p. 77, ll. 6–9).[42] It states that the Indians originally assigned to the access-and-recess motion an amplitude of 8°, which must here be understood as the maximum elongation (in either direction) between the sidereal and tropical reference frames. We are also told that Azarquiel later changed this value from 8° to 10;40°, which comes close to the 10;45° assumed in the Toledan Tables.[43]

The other theory that is here attributed to the Indians appears to rest on the assumpton that precession arises from a motion of the sphere of fixed stars about the poles of the ecliptic, as in the standard Ptolemaic theory, but with periodic reversals of direction that keep the total motion bounded within a range of ±8° (ll. 146–152). It seems very likely that the motion described in this passage corresponds to the *motus polorum* mentioned briefly in the LRT, where its proponents are identified as *magistri ymaginum* (p. 77, l. 6). The expression *magistri ymaginum* ("masters of talismans") leads back—via Arabic sources such as al-Battānī—to Theon of Alexandria's fourth-century *Little Commentary* on the Ptolemaic *Handy Tables*, where the ancient *apotelesmatikoi* are credited with a theory that makes the solstitial points go back and forth by 8°.[44] As before, our text adds that the motion in question makes the tropical year vary but leaves the sideral year constant (ll. 152–154). It also notes that an explanation of these matters can be found in a book *On the Solar Year* written by Azarquiel (ll. 154–155). This important lost work is known only from a handful of references in later sources, one of which is the LRT (p. 79, l. 21).[45]

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[40] On the various manifestations of the access-and-recess theory in medieval astronomy, see Samsó 2020: 579–654, with references to further literature.

[41] On the access-and-recess component of the Toledan Tables, see Mercier 1996; Pedersen (Fritz) 2002: iv. 1542–1566 (PA and PB).

[42] Further parallels may be found in *ʿOlam* III, § 6.2:1–5 (p. 250); *Sefer ha-Ṭeʿamim* I, § 2.12:7 (ed. and trans. Sela 2007: 50–51); *Sefer ha-ʿIbbur* (cit. Sela 2003: 359).

[43] See the remarks on this passage in Samsó 2012: 181–182.

I.V

The first part of *Ptolomeus* concludes with a potted history of previous attempts to measure the length of the tropical year, which appears to be partly inspired by bk. III.1 of Ptolemy's *Almagest*. The sequence of historically attested estimates begins with Meton and Euctemon (ll. 164–175), who have already been mentioned once before (ll. 126–128). We are told that the observational records these astronomers left to posterity did not specify the date when the Sun or any of the other planets crossed the vernal point, which is why Ptolemy bypassed their observations in favour of those carried out by Hipparchus (ll. 185–187). This remark agrees only vaguely with Ptolemy's actual statements in the *Almagest*, where he notes that Meton and Euctemon had confined their observations to the summer solstice, which was difficult to determine accurately, leading him to prefer Hipparchus's equinox observations.[46] In a later passage, Ptolemy counts 571 years between a summer solstice observed by Meton and Euctemon and one of his own observations in AD 140, a figure he subsequently rounds to 600.[47] The claim in manuscript *C* that the two astronomers were active 800 years before Ptolemy (ll. 175–176) hence probably stems from a misreading of '600' as '800', which is easily made if Hindu-Arabic numerals are written in the Eastern forms used in *O*. Another misreading of this sort is likely to have affected the interval separating Ptolemy from Hipparchus. This is 240 years in *C* (l. 177), whereas the LRT (p. 77, l. 21) and the *Sefer ha-ʿOlam* have 280 years,[48] as does *Inter omnes recte philosophantes*,[49] which aligns more closely with the 285-year interval mentioned at one point in the *Almagest*.[50]

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[44] On this background, see Ragep 1996; Sela 2010: 147–148; Mancha 2012: 50–55; Nothaft 2017c: 285–290; 2018b: 157–161.

[45] On this lost work, see Toomer 1969; 1987; Samsó 2020: 654–667.

[46] Ptolemy, *Almagest* 3.1 (trans. Toomer 1998: 137).

[47] Ptolemy, *Almagest* 3.1 (trans. Toomer 1998: 138–139).

[48] *Sefer ha-ʿOlam* I, § 17:1 (ed. and trans. Sela 2010: 62–63).

[49] MS Parma, Biblioteca Palatina, 718–720, fol. 422^{v}.

[50] Ptolemy, *Almagest* 3.1 (trans. Toomer 1998: 138).

Ptolomeus remains broadly true to the account given in the *Almagest* when it describes how Ptolemy found the length of the tropical year (of 365 ¼ – 1/300 days) by comparing his observations with those made by Hipparchus (ll. 181–192). Our author implausibly suggests that these Greek astronomers and their Islamic successors used the same method to determine periods of motions for the other planets, by observing the moments when these planets crossed the vernal point (ll. 173, 181, 187, 192, 203, 206). Even though Ptolemy himself cited Hipparchus as having already considered his own year length of 365 ¼ – 1/300 days,[51] *Ptolomeus* (ll. 177–179) and the LRT (p. 75, ll. 9–10) go no further than stating that Hipparchus thought the tropical year to be slightly shorter than a 365 ¼ days. Similar statements appear in the first versions of the *Sefer ha-ʿOlam* and *Sefer ha-Ṭeʿamim*, where it is claimed that Hipparchus did not know the precise length of the year.[52] This effectively contradicts a passage in the *Sefer ha-Moladot*, where Ibn Ezra writes that Hipparchus's solar year had a rotational excess of precisely 90° (= 6h), implying a length of 365 ¼ days.[53]

Once Islamic astronomers recognized that Ptolemy's year length was excessive, they faced a choice between blaming this error on Ptolemy's own observations or on those made by Hipparchus before him. According to our text, they went with the latter option and retained Ptolemy's data as the basis for deriving a better estimate (ll. 194–213). This claim is broadly in line with the way one of Ptolemy's equinoxes was later used by al-Battānī to establish a shorter year length of 365;14,26d or approximately 365 ¼ – 1/106 days, by comparing this equinox with an observation he made 743 Egyptian years later.[54] The same year length and interval were known to the author of *Ptolomeus*, although *C* once again transmits corrupt numbers, substituting 643 for 743 and 104 for 106 (ll. 206, 210–211).

Our author was aware that al-Battānī used his shorter year length to cast a set of astronomical tables for the meridian of ar-Raqqah in Syria (ll. 214–218). We are also told that he employed the Seleucid era or 'era of Alexander', which began in 311 BC. It is indeed the case that al-Battānī started his collected-year tables on 1 March after 931 completed years of the Seleucid era (= 1 March AD 620).[55] He gave the longitudes of the planetary apogees for 1 March of year 1191 of the same era (= 1 March AD 879),[56] which accounts for the mention of the year 1191 in *Ptolomeus*. However, our author is mistaken in claiming that al-Battānī's years began on 1 October (l. 218) rather than 1 March. While 1 October is indeed the default beginning of the year in the Syriac version of the Julian calendar that appears in al-Battānī's mean-motion tables, al-Battānī himself shifted this beginning back by six months and started in March.

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[51] Ptolemy, *Almagest* 3.1 (trans. Toomer 1998: 139).

[52] *Sefer ha-ʿOlam* I, § 13:8 (ed. and trans. Sela 2010: 58–61); *Sefer ha-Ṭeʿamim* I, § 2.12:4 (ed. and trans. Sela 2007: 50–51).

[53] *Sefer ha-Moladot*, IV.1:5 (ed. and trans. Sela 2014: 182–183).

[54] See al-Battānī, *Opus astronomicum*, c. 27 (ed. Nallino 1899–1907: i. 40–42). Ibn Ezra mentions al-Battānī's year length in several of his works, including the LRT (p. 83, ll. 1–4) and *Sefer ha-Moladot*, IV.1:7 (ed. and trans. Sela 2014: 182–185). Further references are provided in Sela 2014: 344–345.

What diminishes the historical accuracy in *Ptolomeus*'s account even further is the fact that it consistently mentions al-Battānī (d. 929) in tandem with his older contemporary Thābit (d. 901), thereby wrongly suggesting that the two were collaborators (ll. 203–216). The notion that al-Battānī and Thābit agreed on the length of the tropical year is mirrored in the LRT, which claims that Thābit wrote two different books on the solar year, teaching in one of them that the year has 365 ¼ – 1/106 days (p. 76, ll. 8–15). While it is true that a treatise *On the Solar Year* was spuriously attributed to Thābit ibn Qurra, this work mentions no such year length, but rather a mean tropical year of 365;14,33,12d, which is approximately 365 ¼ – 1/134 days.[57]

According to our text, al-Battānī's value received an update and improvement from al-Ṣūfī (d. 986), who found the length of the tropical year to be 365 ¼ – 1/131 days, with a rotational excess of 90° – 2;45° = 87;15° (ll. 219–232). We are further told that this year length was eventually confirmed by Azarquiel (ll. 233–240), which is a claim also made in the first version of Ibn Ezra's *Sefer ha-ʿOlam*.[58] Another bit of information *Ptolomeus* shares about al-Ṣūfī is that this astronomer made observations for a period of 44 years, determining for each of them the time of the Sun's return to the vernal point (ll. 227–230). This is very reminiscent of a passage in the LRT, where one reads that al-Ṣūfī determined his year length through annual observations spread over 40 years (p. 86, l. 27) and that those who later confirmed his result to the nearest minute included Azarquiel, Ibn Sina, and Ibn Yunus (p. 86, ll. 28–30).

Contrary to what one might expect, the LRT takes the year length accepted by these astronomers to be 365 ¼ – 1/136 days (p. 95, ll. 12–15).[59] It associates the corresponding rotational excess of 87;21° with a rate of precession of 1°/70y and a sidereal year whose rotational excess is 92;30° (p. 83, ll. 14–17). In *ʿOlam* III (§ 6.3:13, p. 251) we are instead told that the precession rate of 1°/70y goes together with a tropical year that has the familiar rotational excess of 87;15° and a sidereal year with 92;24°.[60] *ʿOlam* III (§ 6.3:7–10, p. 251) and the LRT (p. 82, ll. 23–27) agree in tracing this length of the sidereal year back to Ptolemy. In the LRT, the same value, which amounts to 365d 6;9,36h = 365;15,24d = 365 ¼ + 1/150 days, is also attributed to Thābit, who supposedly proposed it in one of his treatises on the solar year (p. 76, ll. 14–15; p. 82, ll. 26–29).[61] The sidereal year found in the pseudo-Thābitian work *On the Solar Year* is 365;15,23,34,43d,[62] which would have to be rounded to 365;15,24d to become equal to the length mentioned in the LRT. *Ptolomeus*, for its part, never spells out any 'true' length of the sidereal year but remains content with citing the Indian value of 365 ¼ + 1/120d. It otherwise puts the focus squarely on the length of the tropical year, as this is the parameter needed to understand the mean-motion tables discussed in pt. II.

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[55] Nallino 1899–1907: ii. 72–77, 102–106.

[56] al-Battānī, *Opus astronomicum*, c. 33, 45 (ed. Nallino 1899–1907: i. 72, 114).

[57] See the English translation and commentary in Neugebauer 1962a: 284–285.

[58] *Sefer ha-ʿOlam* I, § 17:10–12 (ed. and trans. Sela 2010: 62–63); cf. *Sefer ha-Moladot*, IV.1:9 (ed. and trans. Sela 2014: 184–185).

[59] See p. 15 above.

Ptolomeus's account of historical observations and investigations of the length of the solar year heavily implies that the pairings al-Battani/al-Ṣūfī and al-Ṣūfī/Azarquiel were each separated by 131 years, as both al-Ṣūfī and Azarquiel saw the equinox regress by precisely one day relative to their predecessor (ll. 222–227, 236–238). Yet this would put al-Ṣūfī in the early eleventh century (140 + 743 + 131 = 1014) and Azarquiel in the mid-twelfth century (1014+ 131 = 1145), making him a contemporary of the author. The LRT, by contrast, erroneously implies that al-Ṣūfī was active in the late eighth century, insofar as it places Azarquiel 300 years after al-Ṣūfī (p. 86, ll. 28–29) while also claiming that Azarquiel made a solar observation in AD 1090 or year 482 of the Hirji era (p. 87, ll. 3–5).

II.i

The second part of *Ptolomeus* is an in-depth account of how to construct mean-motion tables analogous to those the author (i.e., Ibn Ezra) had previously adapted from the *zīj* of al-Ṣūfī (see pt. I, ll. 241–246). In explaining the overall *modus operandi*, the author concentrates on the tables for the Sun, which serve as the basic model for the remaining planetary mean motions. His account begins with a step-by-step explanation of how to derive the length of the tropical year via empirical measurement. We are instructed to observe the time of the Sun's entry into tropical Aries—that is to say, the time of the vernal equinox—and compare this time with a past observation made by a previous astronomer. The interval between these observations—expressed in days, hours, minutes etc.—must then be divided by the pertinent number of tropical years (ll. 3–26). Once the tropical year has been measured in this manner, one can compute the corresponding rotational excess by counting one degree for every four minutes contained in the surplus beyond a complete number of days. According to the specific instructions given in our text, one begins by determining the discrepancy between the length of the tropical year and 365d 6h. This shortfall is then converted into time-degrees, which must be subtracted from 90° to obtain the rotational excess (ll. 27–36).

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[60] As Toomer (1969: 319) and Samsó (2012: 179) have pointed out, a sidereal rotational excess of 92;24° is attributed to Azarquiel by the twelfth-century astronomer Ibn al-Kammād.

[61] See also *Sefer ha-Moladot*, IV.1:3 (ed. and trans. Sela 2014: 182–183); *ʿOlam* III, § 6.3:7–10 (p. 251).

[62] See the translation and commentary in Neugebauer 1962a: 280.

The author further elucidates these operations with an idealized worked example, which assumes that Azarquiel, our hypothetical predecessor, found the vernal equinox in AD 1120 on 14 March at 2 p.m. Our own observation in AD 1140 yields a time of 10 a.m. on the same day, revealing that the equinox has moved 4 hours over 20 years (ll. 39–54).[63] The year length implied by this shift is 365d 5;48h with a rotational excess of 87° (ll. 55–78). A table of expanded years constructed on the basis of this parameter will show an increment of 0;9,51° after 20 years (ll. 79–87) rather than the 0;9° found in the author's own tables (see pt. I, ll. 250–256). This is because the tropical year derived in this example is approximately 0;1h shorter than the 'true' length derived by al-Ṣūfī (ll. 89–94).

It is interesting to observe that, even though *Ptolomeus* makes it perfectly clear that the year length of 365d 5;48h is no more than an example (ll. 88–89), other texts put this parameter forward as a valid estimate. Such is the case in *'Olam* III (§ 6.1:5, p. 250), where the extant Latin translation states that the 'sages' (*sapientes*) who came after Ptolemy proved empirically that the true length of the year is 365 ¼ − 1/120 days, which amounts precisely to 365d 5;48h.[64] *Inter omnes recte philosophantes*, a text directly dependent on *Ptolomeus*, introduces the year length of 365d 5;48h in an example similar to that in II.i, using hypothetical observations by al-Ṣūfī and Azarquiel. It then goes on to claim that this was the year of the 'astronomers', echoing the definition of the tropical year provided at the beginning of I.i.[65] Perhaps mediated by this or other texts derived from *Ptolomeus*, the same year length was to enjoy a significant afterlife in Latin texts on *computus*. One of the first treatises to feature it prominently is the *Compotus Petrus* of 1171, whose author assumed that the calendrical dates of the equinoxes and solstices regress at a rate of 1d/120y. It seems worth noting that the author of this *Compotus* was also familiar with the Tables of Pisa, which is unlikely to be a coincidence.[66]

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[63] It ought to be emphasized that this example was not meant to convey historical information about Azarquiel's observational activities, but is there for didactic purposes only. This was misunderstood by Mercier 1991: 16, who accuses the text of being unreliable.

[64] See my remarks in Sela, Steel, Nothaft, Juste, and Burnett 2020: 205–206.

II.ii

Still using the example of 365d 5;48h, the author next explains how to convert the tropical year into rates of mean motion. The basic operation amounts to converting the length of the year into minutes of time and using the result to divide the 1,296,000 seconds of arc contained in 360° (ll. 96–105). Even though the result of this operation should be 0;0,2,27,52° per minute of time, the author immediately proceeds to derive the rate of hourly motion, which is 0;2,27,52° (ll. 105–116). In the corresponding mean-motion tables, only minutes and seconds of arc are displayed, such that the entry for one hour will appear rounded as 0;2,28° (ll. 117–124). The remainder of II.ii offers simple explanations of how to convert the hourly rate of motion into entries for minutes as well as for days. In one instance, we are told to multiply the minutes and seconds of the entry for one hour by 24 to obtain the entry for one day, which is 0;59,8° (ll. 124–128). Yet this result was clearly found by multiplying the more precise hourly rate of 0;2,27,52° (× 24 = 0;59,8,48°), as otherwise the entry for one day should have been 0;2,28° × 24 = 0;59,12°.

The conversion algorithm in this section has a close parallel in the LRT (p. 95, ll. 15–27), which operates with a tropical year of 365;5,49,22h (possibly an error for 365;5,49,24h). Its computation is more fine-grained, as the zodiac is here resolved into 4,665,600,000 fourths of arc and divided by the number seconds contained in the year, for a rounded result of 0;0,2,28° per minute of time. As in *Ptolomeus*, it is expressly noted that smaller fractions than seconds of arc will not appear in the actual mean-motion tables, whose entries will instead be rounded to the nearest second (p. 95, ll. 29–32).

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[65] MS Parma, Biblioteca Palatina, 718–720, fol. 423^v: "Hanc artem moderni sequentes, quia falsitates convincere nequeunt, indubitanter affirmant annum solarem constare 365 diebus et 5 horis et 48 minutis. Et hic annus 'astronomorum' dicitur, qui rationes circulorum et cetera operi suo sufragantia attendunt, sicut solstitia, equinoctia, obscurationes luminum, nihil sollicitantes de iudiciis, nihil de signatione ymagi⟨num⟩ aut earum motu curantes." The second sentence corresponds to *Ptolomeus*, pt. 1, ll. 8–11.

[66] On the *Compotus Petri* and the subsequent reception of this year length, see Nothaft 2018c: 97–98, 103, 121–125.

II.iii

Once the rate of mean motion has been established, one must proceed to determine a *radix*, which is the mean longitude at a particular epoch corresponding to one of the entries in the table for collected years. The epoch date used for this purpose typically corresponds to the beginning of the calendrical year that underlies the tables in question. As noted at the beginning of this section, astronomers who worked with the Julian calendar could choose between different calendrical conventions, as some began the year in January, others in March, yet others in October (ll. 138–140). Among the various sets of astronomical tables that were cast for Latin Christian users during the twelfth century, a beginning on 1 January characterized the Tables of Marseilles by Raymond of Marseilles (1141) as well as an adaptation of the tables of al-Khwārizmī with an initial *radix* of 1 January 1020 and a canon dated 1145.[67] Ibn Ezra's Tables of Pisa, which are the subject of *Ptolomeus*, place the year's beginning on 1 March, as did al-Battānī when he composed his *Ṣābiʾ Zīj*.[68] Our author, rather than acknowledging this precedent, attributes to al-Battānī a beginning on 1 October (pt. I, l. 218; see pp. 148–149). The only known set of tables in Latin to start the year in this fashion is Petrus Alfonsi's version of the tables of al-Khwārizmī, whose initial *radix* is 1 October 1116.[69] One argument our author gives in favour of starting the year in March is the proximity of this month to the vernal equinox, which is the zero-point for tropical longitudes (ll. 248–258). The same justification is given in the LRT, which states that the start in March is supported by the astrological convention of beginning the year when the Sun enters Aries (p. 87, ll. 18–19). *Ptolomeus* adds to this the curious observation that those who begin their year in October change the beginning of the signs to Libra (ll. 258–259). The only source known to me where this is indeed the case is the *Liber Nemroth*, a Carolingian Latin text with Syriac antecedents.[70]

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[67] For the adaptation of al-Khwārizmī, see pp. 178–179 in the Appendix below. Raymond of Marseilles's tables are edited in Alverny, Burnett, and Poulle 2009: 236–341. Further Christian adaptations of the Toledan Tables are surveyed in Chabás 2019: 103–116.

[68] See n. 55 above.

[69] See Neugebauer 1962b: 133–234.

[70] See Draelants 2018; Nothaft (forthcoming).

To find the mean longitude of the Sun on 1 March, it is expedient to work backwards from the observed time of the vernal equinox, which in the mid-twelfth century fell about two weeks later. Our text notifies us that the equinox can be timed with the aid of “a complete astrolabe,” which is applied as part of a method that uses the Sun’s noon altitude as well as the terrestrial latitude, and which has been “handed down elsewhere” (ll. 141–142: *per astrolabium completum secundum artem alibi traditam per altitudinem meridianam et latitudinem terre*). The distinction between ‘complete’ and ‘incomplete’ astrolabes is familiar from Ibn Ezra’s treatises on the instrument, where it is noted that the horizon plate of a ‘complete’ astrolabe has a separate almucantar (altitude line) for each one of the 90 full degrees of altitude.[71] It is also Ibn Ezra who, in the first version of his *Sefer ha-ʿOlam*, explains how the moment of the vernal equinox can be inferred from observing the Sun’s meridian altitude and comparing it to the known co-latitude of one’s place of observation.[72] This is clearly the method alluded to in our text.

In explaining the subsequent steps, the author again assumes that the observed vernal equinox, and therefore the moment when the true Sun reaches 0°, occurred on 14 March at 2 p.m. (ll. 143–145). To obtain the corresponding mean longitude, it is necessary to determine the value of the solar equation at the time in question. Our author cites an apogeal longitude of slightly more than 87° (l. 156), which is consistent with the position of 27° Gemini given elsewhere in the text (pt. I, l. 26; pt. III, ll. 35–45, 77, 104–112). Manuscripts *C* and *O* are ambiguous as to the precise apogeal longitude. In *O*, the value expressly given is 87;2°, yet the same manuscript gives the result of subtracting the apogee from 0° as 272;57° (l. 157) suggesting an apogeal longitude of 87;3°. Nevertheless, the reading of 87;2° is confirmed by a later step in the computation, where the apogee is subtracted from a mean longitude of 358;1,13° to yield an anomaly of *c.* 270,59° (ll. 159–167). The Tables of Pisa in manuscript O_2 (fol. 30^r) and the treatise *Artis cuiuslibet consummatio* (see § 4) both transmit an apogeal longitude of 87;45°, which according to the latter source is valid for 1193.[73] Assuming this epoch as well as an annual precession rate of 0;0,51° (see p. 141), a longitude of 87;2° would take us back to about the year 1143, and therefore to the very time when the author of *Ptolomeus* constructed his tables (l. 373).

Subtracting the apogee from 0° will yield the Sun’s *true* anomaly, whereas the relevant equation table requires as its argument the *mean* anomaly. Entering the equation table with the true anomaly will accordingly only yield an approximation to the correct equation, as the author himself indicates (ll. 173–178). After this approximate equation has been used to derive the mean longitude, this mean longitude will have to be converted into the corresponding true longitude by computing in reverse. The result will exceed 0° by a certain small amount. In the example at hand, the excess is 0;0,18° (ll. 166–173), which must be subtracted from the mean longitude obtained earlier. This leads to a new value for the mean longitude, which now should be convertible into a true longitude of precisely 0° (ll. 178–188).

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[71] See Rodríguez Arribas 2014: 232, 239, 252, 255.

[72] *Sefer ha-ʿOlam* I, § 14:1–15:8 (ed. and trans. Sela 2010: 60–61).

[73] *Artis cuiuslibet consummatio* 2.26 (ed. and trans. Victor 1979: 282–283).

For the example to be arithmetically coherent, the two values of the solar equation obtained as part of this computational procedure must be 1;58,47° (for an argument of 273°; see ll. 158–160) and 1;59,5° (for an argument of 271°; see ll. 168–170). This way, the first approximation to the mean longitude will be 0° = 1;58,47° = 358;1,13° (l. 164), while the excess to be subtracted at the end will be 358;1,13° + 1;59,5 − 360° = 0;0,18° (ll. 170–172), leading to a final result of 358;1,13° − 0;0,18° = 358;0,55° (l. 186). The first of these equations (1;58,47°) is correctly attested in *C*, whereas *O* has 1;58,41°. Both manuscripts show corrupt values for the second equation (1;59,5°).

Once the mean longitude on 14 March at 2 p.m. has been established, finding the mean motion at the beginning of this date (i.e., at noon) or at any other epoch is merely a matter of subtracting the corresponding mean motion. *Ptolomeus* explains this at some length, even providing indications of how to derive the mean motion on the day of Christ's birth, i.e., 25 December 1 BC (ll. 189–247). While the author's own tables place their initial *radix* at 1 March 1030 (ll. 248–268), he encourages readers to construct their own collected-year tables using a different epoch (ll. 268–270). The example he gives at this occasion (ll. 270–274) suggests that his year of writing was AD 1145 (see p. 5).

II.IV

This section recapitulates and systematizes some of the information already provided in the preceding sections of pt. II. It gives a step-by-step account of how a full set of mean-motion tables can be constructed from the ground up. The way these tables are described corresponds closely to the Tables of Pisa as they are known from Latin manuscripts (see § 2). Some of this material, especially in regard to the tables for months and expanded years, is also closely mirrored in the LRT (p. 96, ll. 4–28).

The basic method is to work upwards from mean motions per minute (ll. 285–293). The final entry of the table for one time-unit will be carried forward as the first entry in the table for the next-highest unit. An adjustment must be made in transitioning from the table for days to the table for months, as the first entry in the table of months corresponds to the motion per 31 days, whereas the table for days stops at 30 days (ll. 346–353). The author describes the sub-tables for minutes and for hours as if they contained a column for thirds of arc (ll. 300–305, 317–320). He admits, however, that most tables omit this column, even as the thirds are factored into the calculation of their entries (ll. 326–335). From the author's earlier remarks about the initial entries in the sub-tables for hours and days (see ll. 117–128), it appears that his own tables only displayed seconds, as is also true of the known copies of the Tables of Pisa (see § 2).

In demonstrating how to compute the mean-motion increment for 20 years, as found in the final line of the table for expanded years, the text refers to an example "in the table" (ll. 410–411: *exemplum in tabula*). This passage only occurs in *C*, where the example in question is the mean motion of the Dragon (i.e., the lunar ascending node). The value given is 19;0,40°, which appears to be a corruption of 19;19,40°. According to the known copies of the Tables of Pisa, this is the motion of the lunar nodes in 365 days, as found in the first line of the expanded-year table. The text in *C* instead appears to refer to the final line of this table (l. 412: *in annis 20*), which may be indicative of a substantial lacuna.

In commenting on the construction of the table for collected years, which are here called *anni coniuncti* (l. 413), the author notes a basic choice between using years of Christ or "years of Alexander" (ll. 418–421), which refer to the Seleucid era known from al-Battānī's *zīj* (see pt. I, ll. 216–217). The same era is mentioned briefly in the LRT (p. 74, l. 22) and receives some further attention in a text on the construction of ephemerides (*In compositione almanac …*), which serves as an appendix to the LRT in two early manuscripts. The Tables of Pisa, with their beginning of the year in March, are here mentioned obliquely, which lends support to the view that we are dealing with another work written or dictated by Ibn Ezra.[74]

III.i

The third part of *Ptolomeus* opens with a detailed description of the eccentric solar model that, in the Ptolemaic tradition, provides the geometric basis for computing the solar equation.[75] In the *Almagest,* the distance between the centre of the Earth and the centre of the Sun's eccentric deferent (or eccentre) is given as roughly 2;30 where the radius of the deferent is counted as 60. To this value of the eccentricity corresponds a maximum solar equation of 2;23° in Ptolemy's equation table.[76] Islamic astronomers working in Ptolemy's wake arrived at more moderate and accurate estimates for the solar eccentricity,[77] explaining why the equation tables used by our author as part of the Tables of Pisa showed a maximum solar equation of only 1;59,8° (see pp. 11–12). He accordingly states that the maximum equation is "about two degrees" (l. 38: *duobus fere gradibus*; also ll. 51–52) and makes an analogous remark about the size of the eccentricity (l. 13: *duobus fere gradibus*). Yet this information remains incomplete insofar as he fails to specify that the size of these two degrees is defined in relation to a deferent radius of 60 degrees or parts. The author also mentions that the Sun's apogee is located at 87° or 27° Gemini (ll. 35–45, 77–78, 104–112), which is consistent with statements made earlier on in parts I (l. 26) and II (l. 156).

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[74] mss Erfurt, Universitätsbibliothek, Dep. Erf. CA 4° 381, fols. 28^{v}–34^{v}, at fols. 29^{r}, 34^{r-v} (s. $xii^{2/2}$); London, British Library, Cotton Vespasian A.ii, fols. 32^{ra}–35^{rb}, at fols. 32^{rb}, 34^{vb}–35^{ra} (s. xii/xiii). On this text, see Nothaft 2021a: 37–39.

In the *Almagest,* Ptolemy devoted ample space to demonstrating the possibility of replacing the eccentric model with an equivalent epicyclic model, in which the radius of the epicycle is equal to the eccentricity of the former.[78] This epicyclic alternative receives some attention in the LRT, where Ibn Ezra presents the eccentric model as an Indian invention whose certainty was later challenged by Ptolemy's demonstration (p. 90, l. 21–p. 91, l. 3). *Ptolomeus,* by contrast, concentrates exclusively on the eccentric version of the solar model, even depicting it in a geometric diagram. It was meant to show the eccentric deferent inside a circle representing the firmament or ecliptic, with twelve equidistant points marked on each of them. These points were numbered alphabetically and arranged anticlockwise, from A to M. The diagram is missing from *O* and drawn incorrectly in *C* (fol. 71^r), where the two circles are perfectly concentric, in defiance of what is described in the text (ll. 41–56). The diagram envisaged by our author must instead have looked similar to Figure 1 below.

Although section III.i was evidently meant to provide some background to the solar equation table that accompanied the Tables of Pisa, the table itself is only described in very general terms (ll. 94–98). Our text provides no method

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[75] On this model and its parameters, see Neugebauer 1975: i. 55–61; Pedersen (Olaf) 2011: 134–154.

[76] Ptolemy, *Almagest* 3.4, 6 (trans. Toomer 1998: 155–156, 167).

[77] Mozaffari 2013.

[78] Ptolemy, *Almagest* 3.3–5 (trans. Toomer 1998: 141–153, 157, 160–161, 163–165).

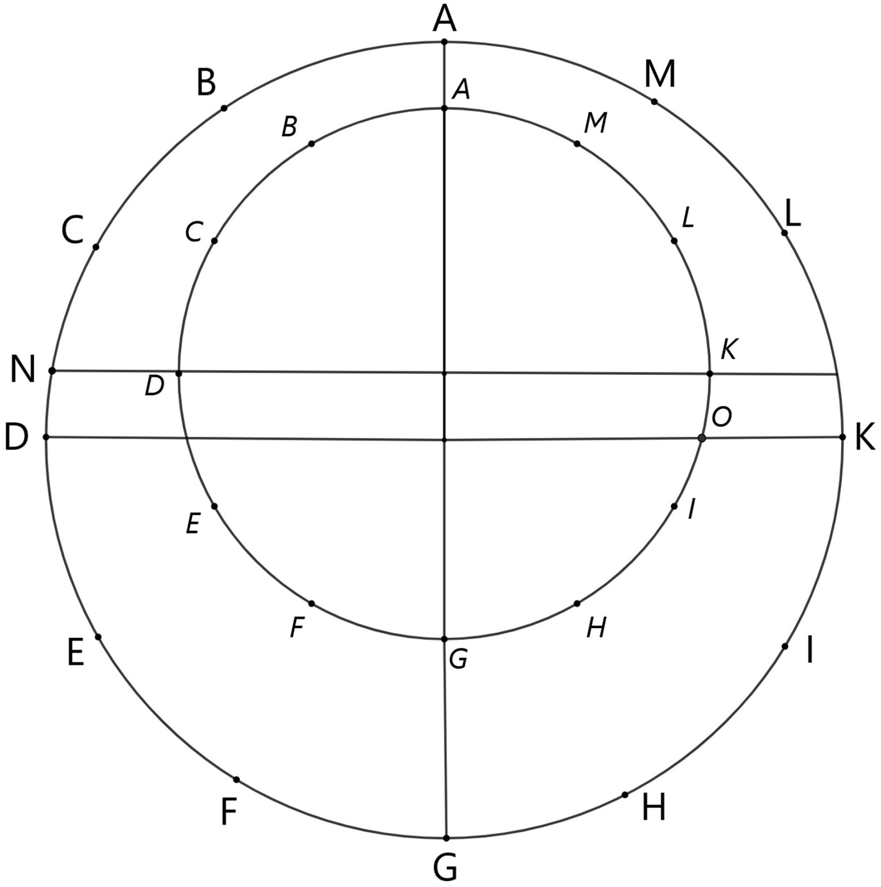

FIGURE 1 Diagram for the solar model in *Ptolomeus*, III.i (reconstruction)

by which its entries can be computed, but merely states that the way these entries grow and diminish has been determined "via the method of arc and chord" (l. 99: *per rationem arcus et corda investigata est*). The author adds that the same is true of the *augmentum horarum* (ll. 99–100), which presumably refers to the increase and decrease of daylight in the course of a year. A similar remark about the "method of arc and chord" is made later on, in III.iii, with respect to the equation tables for the superior and inferior planets (ll. 367–368). We find the same sort of language in the LRT, where it is applied to planetary equations in general as well as to the value of the lunar latitude and solar declination (p. 109, l. 1: *hoc scire poteris per rationem arcuum et cordarum*; p. 109, l. 3: *per arcus et cordas sumitur*; cf. p. 95, l. 12). Yet, whereas the LRT later engages with trigonometry and its applications at considerable length (pp. 124–165), *Ptolomeus* drops the subject immediately and never returns to it—at least in the version available to us. This refusal to go into any further detail about how the equations are tabulated presumably tells us something about the intended audience. The imagined reader of *Ptolomeus* was capable of addition, subtraction, multiplication, and division, but possessed no deeper knowledge of trigonometry. As a result, they would have been capable of computing their own mean-motion tables, as taught in pt. II, whereas the construction of equation tables would have remained beyond their grasp.

III.ii

In a way that is analogous to the previous section, III.ii first sets out the kinematic model underlying the table for the lunar equation and then provides some rules of how to enter this table and compute the equation from it. Under normal circumstances, one would expect the explanatory part to be based on Ptolemy's second lunar model, the core elements of which are shown in Figure 2 below.[79] The Moon, P, here has an epicycle with centre C and radius CP = r = 5;15/60 as well as an eccentric deferent with centre M and radius MC = $R - e$ = 49;41/60. M is removed from the centre of the Earth, O, by OM = e = 10;19/60, such that OC = R = 60 when C reaches the apogee, E. As seen from O, M or—what is the same—the line of apsides connecting O to E rotates in a direction opposite to C at a rate corresponding to the mean elongation between Sun and Moon (η). Consequently, angle COE increases at twice this rate, ensuring that C will always be at apogee when Sun and Moon are at mean syzygy (η = 0° or 180°). At quadrature (η = 90° or 270°), C is at perigee and OC = $R - 2e$.

In the corresponding equation table, the difference between the Moon's mean and true longitude is computed from three components. One is the equation of anomaly, which measures the contribution to the true longitude made by the Moon's changing position on the epicycle (P). It is a function of the true anomaly, defined as the arc between P and the true epicyclic apogee as seen from O. Another, the equation of centre, is the difference between the true anomaly and the corresponding mean anomaly, as found from the relevant set of mean-motion tables. The mean anomaly is equal to the Moon's elongation or position with respect to the mean epicyclic apogee. In Ptolemy's final model, this mean epicyclic apogee is measured from a point diametrically opposed to M on the circle whose radius is defined by OM = e. The value of the equation of centre depends on angle COE and, hence, on the double elongation. A

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[79] On what follows, see Neugebauer 1975: i. 68–99; Pedersen (Olaf) 2011: 159–202.

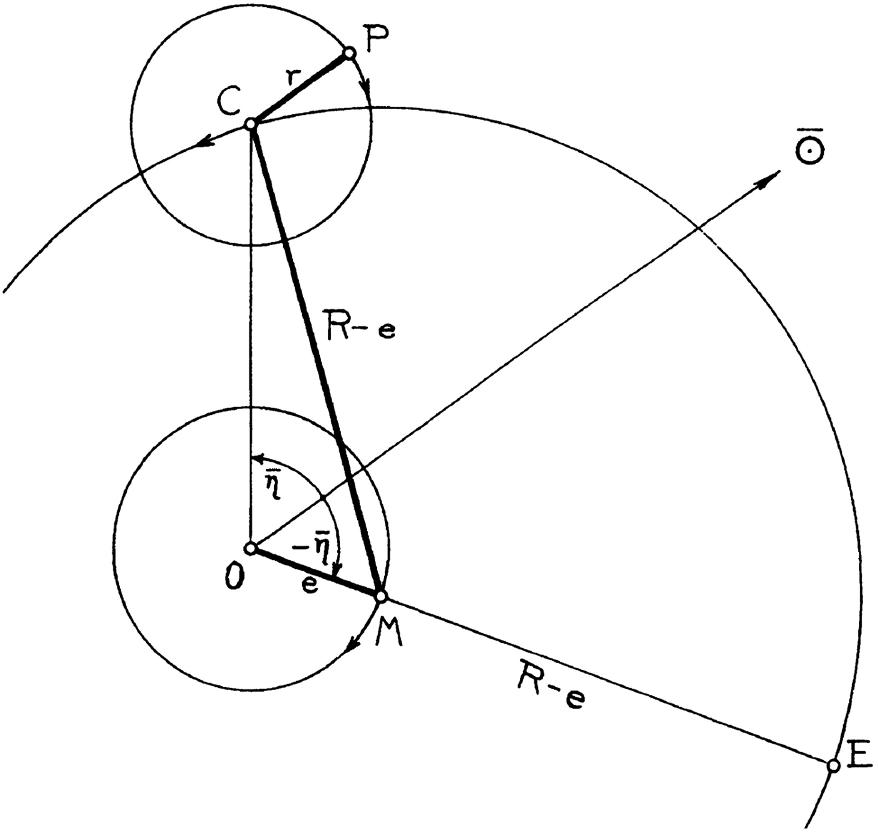

FIGURE 2 Ptolemy's second lunar model (from Neugebauer 1975: iii. 1229)
Note: Republished with permission of Springer, from Otto Neugebauer, *A History of Ancient Mathematical Astronomy*, vol. 3 (Berlin, 1975), p. 1229 (fig. 78); permission conveyed through Copyright Clearance Center, Inc.

third component, which one may call the 'epicyclic increment', represents the increase the equation of anomaly undergoes as the Moon approaches quadrature, which will cause OC to shorten and thus bring the epicycle closer to the observer. The increment is multiplied by a coefficient known as 'minutes of proportion', which are again a function of the double elongation.

Ptolomeus refers to the anomaly as the Moon's *pars* and to the corresponding mean-motion table as *tabula partis* (ll. 239–243), which contrasts with the LRT's use of *portio* (p. 101, l. 35; p. 102, ll. 3; p. 102, l. 22–p. 103, l. 2; p. 105, ll. 10–12; p. 108, ll. 2, 27). Its term for the increment is *directio circuli parvi* or 'equation of the epicycle' (ll. 260–261). The equation of centre appears as *directio puncti* or *directio secundum punctum* (ll. 231–233, 252, 256). The double elongation is called *dupla remotio* (ll. 253–255). In the LRT, the corresponding terms are *equatio brevis circuli* (p. 103, l. 1), *equatio puncti* (p. 102, l. 34), and *remotio duplicata* (p. 106, l. 27; p. 108, ll. 30–31). To obtain the true longitude of the Moon, the sum of the equation of anomaly and its epicyclic increment will be added or subtracted from the Moon's mean longitude, in accordance with what our author calls "the art of [computing] the correction, as with the Sun" (l. 266: *secundum artem directionis sicut et in Sole*). By this, he meant to convey that the equation must be subtracted if the true anomaly is < 180° and added if it is > 180°, in analogy with the way the solar equation is applied.

Ptolomeus describes a diagram depicting the Moon's deferent and epicycle (ll. 140–147), which has not been preserved in either of the two manuscripts. From the text itself, it is not clear whether this diagram was supposed to include a third circle to represent the firmament or ecliptic, as did the diagrams for the Sun (III.i) and Saturn (III.iii). Figure 3 shows only the two circles explicitly mentioned in the text, that is, the epicycle with points ABDC centred on E and the deferent with points NMLKIHGF centred on O. The description of this diagram clearly states that the deferent carries the epicycle towards the east, whereas the epicycle moves the Moon in the opposite direction (ll. 137–138, 142, 147–148). While this agrees with how things are in Ptolemy's second lunar model, most other details mentioned in III.ii amount to an inversion of core elements of this model. This is to an extent also the case in the LRT, which begins its account of the Moon in a way that swaps components of the conventional lunar theory (p. 101, l. 9–p. 103, l. 16). According to this inverted account, the lunar anomaly is a feature of the deferent, whereas the double elongation corresponds to the Moon's motion along the epicycle. The value of the mean motion in anomaly is explained by a motion of the apogee of the deferent in the same direction as the mean motion (*Ptolomeus*, ll. 268–280; LRT, p. 101, ll. 26–29; p. 107, ll. 28–30). The maximum equation of anomaly of around 5° (5;1° according to Ptolemy) accordingly stems not from the size of the epicyclic radius, but from the eccentricity of the deferent (*Ptolomeus*, ll. 125–126, 167–172; LRT, p. 101, ll. 19–22; p. 103, l. 2; p. 105, ll. 1–4). To the epicycle, both texts assign a radius of 2;40°, in accordance with a maximum epicyclic increment of 7;40° – 5° = 2;40 (*Ptolomeus*, ll. 152–153, 220–222; LRT, p. 103, ll. 1–13).

It should be stressed that this inversion of components does not lend itself to a fully coherent explanation of the lunar equation table. In the case of *Ptolomeus*, the overall lack of coherence is aggravated by apparent gaps in the account. It is striking, for instance, that the text offers no clear definition of the equation of centre or the minutes of proportion, which are addressed only as terms in calculating the equation (ll. 255–267). As regards the centre or *punctus*, the text merely indicates that it resides on the deferent and that its equation is zero when the epicyclic centre is at apogee or perigee (ll. 230–235), which

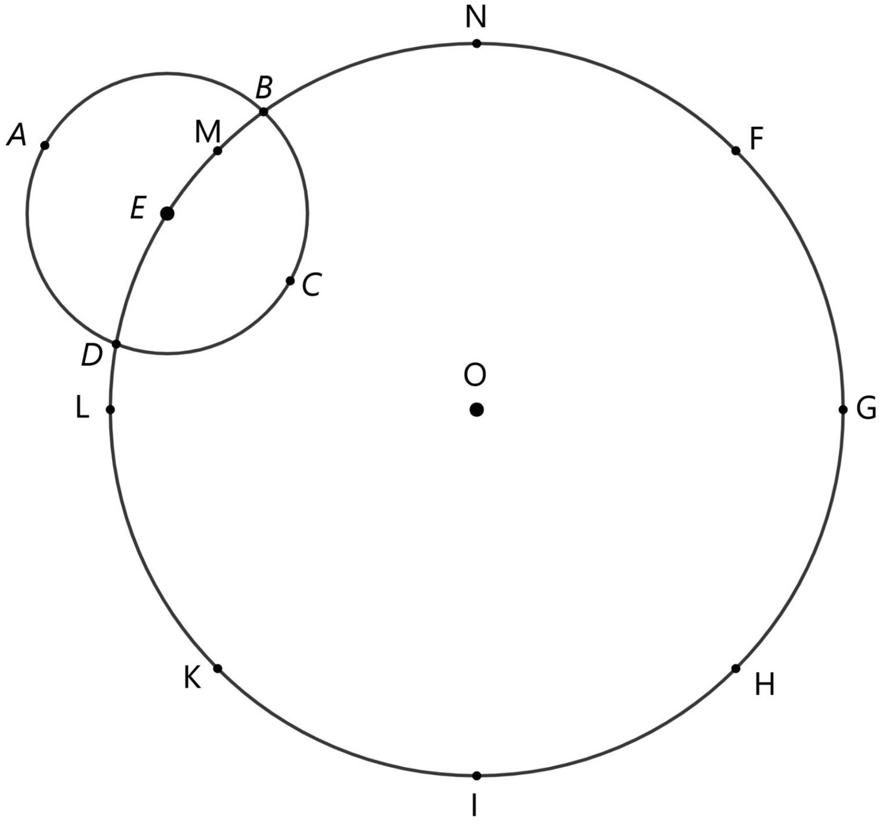

FIGURE 3 Diagram for the lunar model in *Ptolomeus*, III.ii (reconstruction)

leaves it unclear if and how its equation differs from the equation of anomaly (ll. 235–243). A very shadowy role is also played by the third motion in Ptolemy's lunar model, which is the westward rotation of the deferent centre along with the line of apsides. *Ptolomeus*'s only reference to this component comes in a brief passage that introduces a second small circle, which according to Ptolemy carries the deferent centre (ll. 224–227). We are here told that its circular motion causes another variation in the Moon's motion (l. 226: *prestat aliam varietatem motus Lune*). The double elongation is later in the text introduced and described as belonging to "one of the small circles" (ll. 253–254: *uni circulorum parvorum*), without clarifying whether this refers to the aforementioned carrier of the deferent centre or the epicycle.

That the double elongation applies to the epicycle appears to be implicit in the claim that the Moon will always be at syzygy with respect to the Sun when at the epicyclic apogee (ll. 212–216; cf. LRT, p. 103, ll. 13–15). However, to acknowledge the double elongation in this context would have contradicted the author's simultaneous commitment to making the epicyclic motion go from east to west (ll. 137–138, 147–148), seeing as the double elongation can only move in the direction of the Sun. The author even includes an argument that seeks to show that the opposite direction of motion follows logically from the contribution the Moon's epicycle makes to the total equation. He assumes, in accordance with the equation table, that the maximum equation of anomaly is negative when the anomaly is 90°. In his inverted model, the epicyclic centre is then at its first quadrature with respect to the apogee of the deferent, which is point L in Figure 3. Another assumption imposed by the equation table is that the epicyclic increment will always grow in the same direction as the equation of anomaly. Therefore, if the equation of anomaly is negative when the epicyclic centre is at L, the Moon's position on the epicycle must be to the west of the epicyclic centre, that is, towards point B in Figure 3 (ll. 213–223). The problem with this explanation is that it tacitly assumes the Moon will always be in the same part of the epicycle when the epicyclic centre returns to a particular point on the deferent. Yet this is negated by the idea that the Moon performs a full epicyclic revolution twice per synodic month.

From the way the discussion proceeds in LRT, it would seem that its inverted account of the Moon's motions was to some extent influenced by the astronomical tables of al-Khwārizmī. In these tables, the lunar equation consists in a single term, the equation of anomaly. It is a function of the mean distance of the Moon from a steadily moving apogee, whose rate of motion al-Khwārizmī gives as 0;6,40,18,48°/d.[80] This corresponds to the difference between the mean lunar motion and the mean lunar motion in anomaly, which are tabulated side-by-side in al-Khwārizmī's *zīj*.[81] By implication, these tables rely on an epicycle-less lunar model that instead posits an eccentric circle with a rotating line of apsides, which the LRT and the *Ptolomeus* both depict as an Indian invention (*Ptolomeus*, ll. 153, 281; LRT, p. 86, ll. 1–2; p. 89, ll. 23–24; p. 98, ll. 13–14; p. 102, ll. 21–24; p. 104, l. 34–p. 105, l. 4; p. 107, ll. 27–28).[82]

Even though the known versions of al-Khwārizmī's *zīj* all tabulate the lunar mean motion in anomaly rather than the apogeal motion, the LRT asserts that the Indians composed tables for the latter (p. 101, ll. 32–33). According to this text, it was only their Islamic successors, the *magistri probationum*, who simplified the method by instead tabulating the Moon's motion relative to the apogee (p. 102, ll. 1–3). Rather surprisingly, we are also told that Ptolemy, the Indians, and the *magistri probationum* were unanimous in attributing to the lunar apogee a daily motion of 0;6,41° (p. 101, ll. 26–29; cf. *Ptolomeus*, ll. 268–272).[83] Taken literally, this would imply that Ptolemy and his Islamic successors agreed with al-Khwārizmī that the mean motion in anomaly corresponds to the difference between this apogeal motion and the Moon's mean motion. This assumption appears to be one of the roots of the inverted account, which effectively treats Ptolemy's second lunar model as an extension of the simpler Indian model. There is a certain sense in which this may be deemed correct, as Ptolemy indeed began his investigation into the Moon's motions with a single-anomaly model, which was equivalent to his final model at syzygies. However, he formulated two versions of this model, one of them based on an eccentric deferent with rotating line of apsides, the other on a concentric deferent with epicycle. From his own account in the *Almagest*, it follows that his second lunar model was in fact a modification of the epicyclic version, which introduced a crank-type mechanism to increase the epicycle's apparent radius at quadrature. The modification in question was necessitated by observations that showed that the maximum equation of anomaly at quadrature was 7;40° rather than 5°, as predicted by the initial model.[84]

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[80] See ch. 18 of the Latin canons edited in Suter 1914: 15.

[81] See Suter 1914: 117–119 (Tab. 6–8).

[82] The 'Indian' lunar model is also mentioned in the text on ephemerides that is appended to the LRT in two manuscripts (see n. 74). See Erfurt, Universitätsbibliothek, Dep. Erf. CA 4° 381, fols. 31^{v} (s. XII$^{2/2}$); London, British Library, Cotton Vespasian A.II, fol. 33va (s. XII/XIII).

Ptolomeus gives us a strikingly different account of how Ptolemy came to solve this problem, claiming that he added an epicycle to modify the eccentric version (ll. 184–211). The same impression is created by certain passages in the LRT (p. 98, ll. 14–16; p. 103, ll. 8–12), which portray the epicyclic version of the initial model as a Persian invention (p. 101, ll. 23–24; p. 105, ll. 4–6). In contrast to *Ptolomeus*, however, the LRT eventually departs from its inverted account of the second model, as it proceeds to lay out the Moon's different motions along conventional Ptolemaic lines (p. 104, l. 17–108, ll.–34). At one point, it even acknowledges that Ptolemy attributed the motion in anomaly to the epicycle rather than the deferent, thereby contradicting the Indians (p. 108, ll. 2–3). This is never clarified in *Ptolomeus*, in which the inversion is perpetuated even after the rules for the equation table have been introduced. Section III.ii here concludes with a discussion of the Moon's apogeal motion, which presupposes an 'Indian' interpretation of the first anomaly as caused by the eccentricity of the deferent (ll. 268–285).

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[83] This alleged daily apogeal motion of 0;6,41° is equal to the difference between the daily lunar mean motion and the daily lunar mean motion in anomaly according to the Tables of Pisa: 13;10,35° − 13;3,54° = 0;6,41°.

[84] Ptolemy, *Almagest* 4.5–6, 5.2–3 (trans. Toomer 1998: 180–203, 220–225). The steps by which Ptolemy developed his lunar model are discussed in Del Santo and Strano 1996; Goldstein and Bowen 1999; Recio 2021.

The inverted interpretation of Ptolemy's second lunar model was not exclusive to *Ptolomeus* and LRT.[85] In fact, it reappears in the canons that accompany the Tables of Pisa in *K* (fols. 191^{va}–193^{vb}), which preserves a Parisian recension made around 1250. The maximum equation of anomaly is here asserted to be equal to the eccentricity of the deferent,[86] whereas the entries of other columns in the lunar equation table are portrayed as functions of the Moon's position on its epicycle. By implication, the rate of epicyclic motion is here assumed to correspond to the double elongation rather than the mean motion in anomaly. While this makes for a striking parallel with the accounts of the lunar model in *Ptolomeus* and the LRT, these similarities are insufficient proof that either of them influenced the canons in *K*. Rather than drawing on an existing source, it is possible that the author of these canons simply reported his own interpretation of the headings to individual columns in the equation table. Someone who looked at the lunar equation through the prism of the eccentric solar model and its equation could easily arrive at the mistaken conclusion that the Moon's *equatio argumenti* applied to arcs on an eccentric deferent that were measured from the apogee. Similarly, to someone unfamiliar with the details of Ptolemy's second lunar model the use of expressions such as *equatio diversitatis circuli brevis* to denote the epicyclic increment could suggest that the entries in the corresponding column (labelled *tabula circuli brevis* in *K*) depend on the angular distance between the Moon and the apogee of its epicycle.

Caveats of this nature are also in order when it comes to two anonymous Latin texts to which attention was drawn by Fritz S. Pedersen. One of these, beginning *Investigantibus astronomiam primo sciendum* …, was edited by Pedersen on the basis of two full copies and several fragments. It appears to date from the last quarter of the twelfth century.[87] The other text remains unpublished and almost completely unstudied. It exists in two significantly different recensions, which are transmitted, respectively, in MSS Toledo, Archivo y Biblioteca Capítulares, 98–22 (= *T*), fol. 1$^{\text{ra–vb}}$ (s. XIII) and Leipzig, Universitätsbibliothek, 1487, fols. 53$^{\text{r}}$–67$^{\text{r}}$ (s. XIV).[88] Of the thirteenth-century copy in the Toledo manuscript, which begins *Motuum Solis alius est medius* …, only the first leaf has survived, with only the two columns on the verso-side remaining fully legible. The copy in the Leipzig manuscript begins *Nostri temporis astronomici* … and appears to be complete, although the text here omits certain lines and passages found in the Toledo manuscript. What both recensions have in common is that they provide rules and explanations for the Tables of London, which were themselves an adaptation of the Tables of Pisa.[89] Among the material absent from *Nostri temporis astronomici* are some references to the present year 1181, which provide a date for *Motuum Solis alius est medius*.[90]

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[85] In addition to the sources mentioned in what follows, attention ought to be drawn to the non-standard description of a lunar model in an anonymous text on the Tables of Marseilles (see § 5 of part II of this volume), which exists in two different versions, *Infra signiferi poli regionem* … in *A*, fols. 28^{va}–34^{va}, and *Circulorum alius est sub quo* … in MS Firenze, Biblioteca Nazionale Centrale, Conv. soppr. J.II.10, fols. 227^{ra}–231^{va} (s. XIII/XIV). The lunar anomaly is here once again interpreted as the distance of the epicyclic centre from the apogee on the eccentric deferent.

[86] *K*, fol. 192^{ra}: "Tabula equationis argumenti sic fit. Quanta est ecentricitas ecentri Lune, tanta est equatio argumenti maxima secundum verum sumpta, scilicet 5 graduum in quadrato ab auge ecentrici."

[87] Pedersen (Fritz) 1990.

The lunar models described in these texts are identical in most essential respects. They are also more complete and to an extent more coherent than what we find in *Ptolomeus* and the LRT. As before, the Moon's motion in anomaly (*argumentum*) is measured on the deferent and interpreted as the difference between its mean motion and the motion of the apogee. The double elongation is the parameter governing the Moon's motion on the epicycle. All lunar motions are from west to east. The equation of centre is here defined as the angular distance between the Moon and its epicyclic centre, as seen from the centre of the Earth (as stated in *Investigantibus*) or from the centre of the deferent (as stated more adequately in *Motuum Solis*). Finally, the minutes of proportion and increment are there to factor in the Moon's changing distance with respect to the firmament as it moves on the epicycle, which influences the total equation.[91] There is here no mention, and indeed no need, for the small circle carrying the deferent centre, which makes only a brief appearance in *Ptolomeus* (ll. 224–227).

The author of *Investigantibus* supports his description of the Moon's epicyclic motion by drawing an analogy with the superior planets, which all move on their epicycles in an easterly direction at a rate equivalent to the daily mean elongation from the Sun. He supposes that the Moon doubles this rate on account of the small size of its epicycle, but otherwise moves in the same manner.[92] Rather than being ignorant of the conventional reading of Ptolemy's lunar model, he explicitly argues against it, attributing its outlines to al-Farghānī and his followers.[93] In summarizing their position, he relies on erroneous definitions of the equation of centre and the epicyclic increment, which he drew from the *Liber de motibus planetarum*, an anonymous twelfth-century text.[94] He subsequently attempts to prove that al-Farghānī's model fails at explaining the actual rules of using the equation table.[95] It also occurs to him, however, that the rules themselves are incomplete insofar as they make no distinction between the mean Moon and the mean epicyclic centre, which are identical only if the Moon is at the epicyclic apogee or perigee. Even though the difference that arises at other times has already been accounted for by the equation of centre, as erroneously defined by the author, he nevertheless sees the need to invent a further explanation. He does so by distinguishing between a true and a mean apogee on the deferent and postulating that the true apogee oscillates around the mean apogee to compensate for the Moon's epicyclic motion.[96]

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[88] The text in the Leipzig manuscript was mentioned by Pedersen (Fritz) 1990: 212, 215. For further discussion, see § 6 in the introduction to Part II of this book.

[89] See n. 50 in § 2 above and § 4 in the introduction to Part II.

[90] *T*, fol. 1$^{\text{rb}}$.

[91] *Investigantibus*, ll. 73–74, 96–119 (ed. Pedersen [Fritz] 1990: 237, 241–244); *Motuum Solis alius est medius* (*T*, fol. 1$^{\text{va}}$–b); *Nostri temporis astronomici* (Leipzig, Universitätsbibliothek, 1487, fols. 55$^{\text{v}}$–56$^{\text{v}}$).

Such criticisms and complications are completely absent from the account of the Moon and its equations included in *Motuum Solis alius est medius* and *Nostri temporis astronomici*, which provides a concise outline the same inverted model we find in *Investigantibus*, but without the oscillating apogee. Both recensions of the text describe a diagram depicting the relevant model, although the diagram itself is missing from the Toledo manuscript (*Motuum Solis*) and left incomplete in the Leipzig manuscript (*Nostri temporis astronomici*).[97] In a passage only included in *Motuum Solis*, the view according to which the epicyclic motion is from west to east is attributed to a certain Master Alanus "and his master" (*T*, fol. 1va: *secundum magistrum Alanum et eius magistrum*). Having described the components of the inverted model and their relation to the tabulated equations, the text in both recensions moves on to give an analogous account of the conventional model, which is duly attributed to Ptolemy.[98] The author signals no preference for either option.

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[92] *Investigantibus*, Jn 102–105 (ed. Pedersen [Fritz] 1990: 242).

[93] *Investigantibus*, Jn 81–83 (ed. Pedersen [Fritz] 1990: 238–239).

[94] *Investigantibus*, Jn 84–86 (ed. Pedersen [Fritz] 1990: 239). The influence of the *Liber de motibus planetarum* is documented in Nothaft 2018b: 162–163. See also Pedersen [Fritz] 1990: 215–216.

[95] *Investigantibus*, Jn 87–95 (ed. Pedersen [Fritz] 1990: 239–241).

[96] *Investigantibus*, Jn 120–129 (ed. Pedersen [Fritz] 1990: 245–247).

[97] MSS Leipzig, Universitätsbibliothek, 1487, fols. 55^{v}–56^{v}; *T*, fol. 1va–b.

[98] MSS Leipzig, Universitätsbibliothek, 1487, fols. 56^{v}–57^{v}; *T*, fol. 1^{vb}.

Pedersen classified *Ptolomeus* as a "cognate text" of *Investigantibus* on the grounds that it offers "[t]he most complete counterpart" to the lunar theory presented there, preserving all the pertinent features "except for the direction on the epicycle."[99] A careful reading of III.ii against *Investigantibus* indicates, however, that the differences between these texts are rather substantial. As mentioned before, *Ptolomeus* depicts the radius of the epicycle as equal to the maximum epicyclic increment, which implies that the increment in *Ptolomeus* plays a similar role to the equation of centre in *Investigantibus*. The latter text treats the increment in a way that is somewhat closer to the conventional model, describing it as a variation of the equation of anomaly due to the changing distance of the Moon from the centre of the Earth. It should be noted, moreover, that these divergences in interpretation account for the contrary directions of epicyclic rotation asserted in these two sources. As already mentioned, the westerly rotation of the epicycle in *Ptolomeus* follows from the author's observation that the equation of anomaly, as augmented by the epicyclic increment, is negative when the anomaly is < 180°. By contrast, the model proposed in *Investigantibus* requires a rotation from west to east, seeing as the equation of centre is positive where the double elongation is < 180°.

Given these differences, I am inclined to conclude that the inverted model in *Investigantibus* was devised independently from *Ptolomeus* by someone attempting to reconstruct a sound kinematic model of the Moon from the columns in the lunar equation table before him. I see no clear signs that *Ptolomeus* influenced this account either directly or indirectly.

III.iii

Unlike the section devoted to the Moon, which deviates to a serious extent from Ptolemaic orthodoxy, *Ptolomeus*'s account of Saturn in III.iii sticks close to the model of the superior planets familiar from the *Almagest*,[100] notwithstanding certain simplifications. The same is true of the parallel account offered in the LRT (p. 109, l. 5–p. 114, l. 30), which also covers Saturn's motion in latitude. An element missing from both these texts is the equant point, which Ptolemy had introduced to distinguish between the centre of the deferent and the centre of uniform motion for the epicyclic centre. This omission was justifiable by the fact that the equant point does not play an overt role in the rules that govern

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[99] Pedersen (Fritz) 1990: 211 (classification as cognate text), 215 (lunar model).

[100] See Pedersen (Olaf) 2011: 261–294.

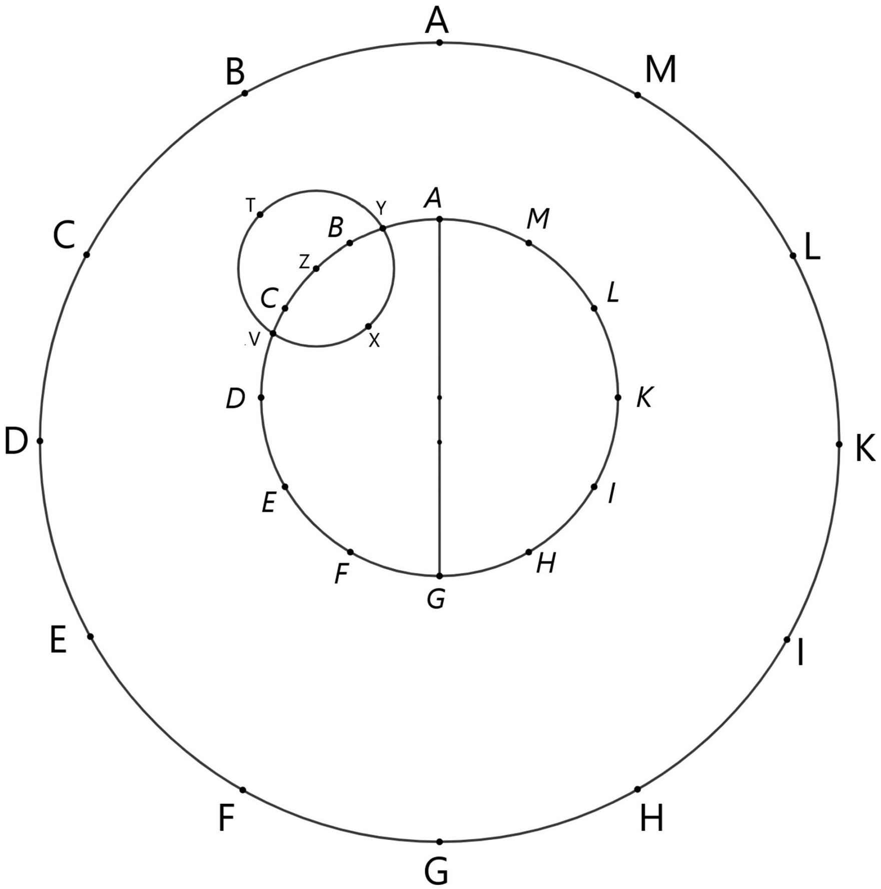

FIGURE 4 Diagram for the model of Saturn in *Ptolomeus*, III.iii (reconstruction)

the corresponding equation table. To explain the columns of this table, it was sufficient to refer to the two motions the planet performs on the epicycle and eccentric deferent. *Ptolomeus* originally presented these circles in a diagram, which surrounded the deferent with the larger *circulus firmamenti* centred on the Earth (ll. 400–416). Neither manuscript preserves any trace of this diagram, an approximation of which is offered in Figure 4. In describing it, the author situates the apogee of Saturn's deferent at 10° Sagittarius (ll. 405–406), or 250°. This is not too far removed from the 251° mentioned in the LRT (p. 109, l. 16), the 250;42° recorded in manuscript O_2 (fol. 32^r) of the Tables of Pisa,[101] or the 250;10° in the list of apogees for 1100.[102]

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[101] See n. 24 above.

[102] See n. 25 above.

In contrast to the epicycle in the lunar model, Ptolemy's planetary epicycles have the same direction of motion as their deferent, west to east (ll. 302–303). Our text notes that Saturn's period of epicyclic revolution is 378 days with a surplus of hours (ll. 303–304), which will be given a more precise rendering in III.iv (ll. 672–673). Readers are also reminded that the *punctus* or epicyclic centre of the planets plays an equivalent role to the *pars* or anomaly in the models for the Sun and Moon (ll. 361–362). This remark is consistent with the way section III.ii implicitly defined the *pars* as an arc on the deferent rather than on the epicycle. In the case of the planets, their anomaly, here again called *pars*, is reckoned from the epicyclic apogee, at which point the planet is found to be in conjunction with the Sun. According to Ptolemy's full theory, this conjunction occurs when the planet is at the mean apogee of its epicycle, which is defined with respect to the equant point, whereas the true apogee is determined with respect to the centre of the Earth. *Ptolomeus* tends to obscure this distinction, speaking simply of the "apogee of the small circle" (ll. 374, 378, 381). What it does acknowledge, however, is that the equation of centre corresponds to the gap between the epicyclic apogee and the point where the planet was in conjunction with the Sun 'according to the firmament' (ll. 373, 377, 380–381). The latter must here be understood as the true epicyclic apogee.

In both III.iii and the following section (III.iv), Saturn's maximum equations of anomaly and centre are cited, respectively, as 6;13° (ll. 389, 435, 457–469, 483, 650–651, 669) and 6;31° (ll. 650, 665). These are standard Ptolemaic values, which one also encounters in the LRT (p. 145, l. 33; p. 146, l. 12) and in the equation tables accompanying the Tables of Pisa in *K* and *V* (see pp. 12–13). One of the simplifying assumptions our text makes in explaining these equations is that the maximum equation of anomaly always arises when the planet's position on the epicycle has reached 90° from the apogee, at which point the planet's body is supposedly found on the deferent (ll. 382–399, 433–442, 457–488). The LRT is more cautious in noting that the maximum of will be reached before 96° (p. 146, l. 14), which matches the way the equation tables in *K* and *V* correlate the maximum equation of anomaly of 6;13° with an argument of 94°–99°.

For the positive or negative increment necessitated by the changing distance of the epicycle from the observer, the text repeatedly mentions a maximum value of 0;19° (ll. 472–485, 652). According to the aforementioned equation tables, 0;19° is the subtractive difference at greatest distance (*longitudo longior*) for an anomaly of 90°. However, the same tables show that the increment can reach up to 0;21° at maximum distance and 0;25° at minimum distance (for anomalies around 105°). An outright error occurs where the author specifies the decrease the maximum increment undergoes as the epicyclic centre moves from apogee to quadrature, represented by points A and D in the diagram (Figure 4). According to the text in both manuscripts, the increment is 1/3 of 0;19° at B and 2/3 of 0;19° at C (ll. 505–520), which must be switched around.

The author twice notes that the columns for minutes of proportion in the equation tables have either *minuit* or *crescit* written above them, so as to help users decide whether the increment must be additive or subtractive must be additive or subtractive (ll. 499–502, 654–658).[103] These specific words are indeed preserved in the relevant columns of the equation tables in *N* (fols. 28^r–42^v), whose links with the Tables of Pisa have been discussed above (see p. 12). Analogous instructions are also inscribed in the 'Pisan' equation tables in *V*, although here the wording is changed to *minue* and *auge*. In *K*, the words *minuitur* and *crescit* are added exclusively to the table of Mercury (below the main heading).

Once the increment has been added to or subtracted from the equation of anomaly, the result is the 'final' equation of anomaly, or *ultima directio partis* (ll. 579–580). In the LRT, the corresponding term is *finis equationis* (p. 113, ll. 33–35 etc.). If the mean centre has already been rectified by applying the equation of centre, adding or subtracting the 'final' equation will yield the 'twice-equated' centre (*bis directum*) (ll. 593–594). Adding this twice-equated centre to the position of apogee subsequently yields the true longitude of the planet in question (ll. 595–602). Alternatively, one may proceed by applying the equations to the mean longitude of the planet rather than its mean centre (ll. 610–621).

In its original form, the text of III.iii apparently included a worked example that provided specific values for the mean Sun, mean centre of Saturn, and the apogee of Saturn. Manuscript *O* breaks off at this very point, perhaps because the scribe did not wish to include the example. In *C*, the example is omitted except for the names of specific parameters, such as "mean motion of the centre of Saturn" (*medius cursus puncti Saturni*), which are preserved without the corresponding numbers (ll. 622–624).

III.iv

It is expressly noted at the beginning of this section that the explanations offered in III.iii are for the most part also applicable to the equations of the remaining four planets. Differences in their respective maximum equations of centre and anomaly are a simple consequence of the different sizes of their epi-

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[103] Such column headings (*addatur/minuatur*) for all five planetary equation tables were already presupposed by Raymond of Marseilles for his Tables of Marseilles (1141), which

TABLE 2 Synodic periods and longitudinal increases of the planets according to *Ptolomeus*, III.iv; textual emendations are indicated by square brackets

	Mean motion	**Mean motion in anomaly**	**Synodic period**	**Longitude increase**
Saturn	0;2°/d[a]	0;57°/d	378d 2;9h	12;39,46°
Jupiter	0;4,59°/d	0;54,9°/d	398d 21;15h	33;9,36°
Mars	0;31,2[6]°/d	0;27,42°	779d 22;2[2]h	48;44,6°°
Venus	–	–	583d 21;57h	–
Mercury	–	3;6,24°	115d 21;5h	–

a For Saturn, see section III.iii, ll. 307–309, 351–352, 383.

cycles and eccentricities (ll. 661–672). While this is correct as a general observation about Jupiter, Mars, and Venus, the author fails to note that Ptolemy's model for Mercury includes an additional circular motion of its deferent centre or line of apsides, which entails slight changes in the way the epicyclic increment is computed.[104] A brief allusion to this is included in the LRT (p. 113, ll. 15–16). As *Ptolomeus* points out at the end of III.iv, the two inferior planets are also distinct from the superior ones in that conjunctions with the Sun can occur when the planet is at its epicyclic apogee *or* its epicyclic perigee, whereas the conjunctions of the superior planets with the Sun are limited to the apogee (ll. 724–726).

Most of the remainder of III.iv is taken up with basic numerical information about each planet's rate of mean motion and synodic period, as summarized in Table 2 above. For the three superior planets, *Ptolomeus* also cites the increase in mean longitude over one synodic period. Contrary to what the text itself implies, the synodic periods and longitudinal increases cited in III.iv were not actually computed from the rounded mean-motion rates listed in Table 2. Rather, it appears that the author based himself on the more precise parameters implicit in the Tables of Pisa. Table 3 shows the daily mean motions and daily mean motions in anomaly that can be extracted from the motion in 20 years shown in the expanded-year tables for the Sun and the five planets. In each instance, the result has been rounded to the fifth sexagesimal-fractional place.[105]

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were an offshoot of the Toledan Tables. See Raymond of Marseilles, *Liber cursuum planetarum* 2.8g, 2.10c (ed. Alverny, Burnett, Poulle 2009: 212, 214).

[104] See Pedersen (Olaf) 2011: 319–328.

[105] See Nothaft 2018a: 298.

TABLE 3 Rates of mean motion in the Tables of Pisa

	Daily mean motions	**Mean motion in anomaly**
Sun	0;59,8,19,42,45°	–
Saturn	0;2,0,34,30,48°	0;57,7,45,11,57°
Jupiter	0;4,59,16,20,42°	0;54,9,3,22,3°
Mars	0;31,26,38,46,5°	0;27,41,40,56,40°
Venus (arg.)	–	0;36,59,29,35,36°
Mercury (arg.)	–	3;6,24,8,17,44°

In the case of Saturn, the mean motion in anomaly listed in Table 3 would imply a synodic period of 378d 2;9,54…h, in rough agreement with the period cited in *Ptolomeus*. However, multiplying this period by the daily mean motion implies a longitude increase of 12;39,48…° rather than 12;39,46°. Jupiter's mean motion in anomaly would give us a synodic period of 398d 21;14,30,35…d, which one could plausibly round to 398d 21;15h, as stated in the text. For the longitude increase, the values in Table 3 suggest 33;9,35,18…° (*Ptolomeus*: 33;9,36°).

The full parameters for Mars listed in Table 3 suggest a synodic period of 779d 22;22,42…h and a longitude increase of 48;44,16…°. We get numbers close to those given in the text if we simplify the mean motion to 0;31,26,38° and the mean motion in anomaly to 0;27,41,41°. Implicit in these numbers is a synodic period of 779d 22;22,4…h (*Ptolomeus*: 779d 22;22h) and a longitude increase of 48;44,5,42…° (*Ptolomeus*: 48;44,6°). Similarly, synodic periods for Venus and Mercury that are reasonably close to those mentioned in *Ptolemaeus* result if the values in Table 3 are rounded to the third sexagesimal-fractional place. For Venus, this gives us a daily motion of 0;36,59,30° and a synodic period 583d 21,58,1…h (*Ptolomeus*: 583d 21;57h). For Mercury, the respective values are 3;6,24,8°/d and 115d 21;4,57…h (*Ptolomeus*: 115d 21;5h).

III.V

This section appears to have been intended as a commentary on a separate table for planetary stations, which is entered with the true centre of the relevant planet to find the arcs of true anomaly at which the planet will be stationary before each retrograde arc. The author uses the diagram for Saturn (see III.iii) to explain the rationale behind a table of this type, showing how stations and retrogradations arise from the interplay between the planet's motions along the epicycle and deferent (ll. 732–768). Explanations of the same phenomenon can also be found in the LRT, which has a separate discussion of stations and retrogradations for each of the five planets (p. 114, l. 33–p. 116, l. 10; p. 117, l. 29–p. 118, l. 18; p. 119, l. 23–p. 120, l. 15; p. 121, ll. 16–31; p. 123, ll. 2–19). It also gives the same approximate value of 115° for the first station of Saturn (p. 115, l. 27) that we find in *Ptolomeus* (l. 761).

Separate tables for the planetary stations are known from al-Battānī's *Ṣābiʾ Zīj* as well as from Ptolemy's *Handy Tables*, yet in these cases the tables feature a further column for the second station.[106] *Ptolomeus*, by contrast, only mentions a column for the first station (ll. 789–790), as was also commonly added to equation tables. Copies of the Toledan Tables normally attach the column for the first station to the main equation tables, although there are exceptions where the first station is hived off to a separate set.[107] This is also the case in *N* (fol. 44^v), which combines the five planets into a single one-page tables. Its entries are wrongly declared to be "according to the *Almagest*" (*secundum Almagesti*), even though the values correspond to the Toledan ones.[108] A close link between the table in *N* and the table alluded to in III.v is invalidated by the fact that the arguments in *N* begin at 6° and continue to rise by steps of 6°, whereas *Ptolomeus* assumes the presence of an entry for 1° (l. 797).

The equation tables in *K* and *V* follow the much more widespread format of showing the first station as the rightmost column of the equation tables. Speaking about these equation tables, the author of *Ptolomeus* instructs us to "inscribe" the first station where "the following line surpasses the preceding one by the amount of the daily motion of the centre" (ll. 777–779: *notabis primam stationem ubi inveneris sequentem lineam tantum superare precedentem quantus est motus puncti in die uno*). Although the text fails to specify the column to which this rule applies, it seems clear that it must refer in some way to the equation of anomaly. For the planet to be stationary, this equation must diminish by the amount of the motion of the epicyclic centre in order to compensate for the latter. Accordingly, the text should have stated that the preceding line must surpass the following one.

The motion of the epicyclic centre employed in this rule is the planet's mean motion, which is *c.* 0;2°/d in the case of Saturn (ll. 782–786). A look at the relevant equation table in *K* (fol. 186^r) and *V* (fol. 24^r) shows that the equation of anomaly decreases in steps of 0;2° per when the true anomaly is between 113° and 116°, which is in rough agreement with the values listed in the column for the first station (112;44° to 115;33°). The lowest value in this column, shown for a mean centre of 1°, is 112;44°, which agrees exactly with what is mentioned in this regard in *Ptolomeus* (ll. 796–800). Some uncertainty nevertheless remains about the presence of this column in the equation tables that the author had before him. While his remark about 'inscribing' the first station could be construed as an allusion to such columns (l. 777), this is then followed by comments on what appears to be a separate *tabula* for the first station, quite as if the columns had been separated from the equation tables and united to form their own table.

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[106] See Nallino 1899–1907: ii. 138–139; Pedersen (Fritz) 2002: iv. 1307 (EB22); Chabás and Goldstein 2012: 117–119.

[107] Pedersen (Fritz) 2002: iv. 1307 (EB21). See also Raymond of Marseilles, *Liber cursuum planetarum*, Tab. 13–17 (ed. Alverny, Burnett, and Poulle 2009: 306–320).

[108] Compare the table of stations in Ptolemy, *Almagest* 12.8 (trans. Toomer 1998: 588).

III.vi

The final section of pt. III, as transmitted in manuscript *C*, offers an elementary account of the fact that all planets other than the Sun undergo a motion in latitude. We are told that the deferents of these planets are inclined relative to the ecliptic, which is here referred to as "zodiac" (*zodiacus*) and "path of the Sun" (ll. 820, 830, 833, 839). The inclination makes the deferent intersect with the ecliptic at two nodes, which in the case of Mars happen to be located perpendicularly with respect to the line of apsides (ll. 855–856).

The relative locations of the planetary nodes and apogees/perigees will remain constant, as they jointly undergo precession along with the sphere of fixed stars. According to III.vi, the rate of this motion is 1°/100y (ll. 817–818), which is at odds with the precession rate of 1°/70y that Ibn Ezra appears to have used when composing the Tables of Pisa (see p. 141). Nevertheless, the allocation of this section in the manuscript to *Ptolomeus* is supported by a comparison with the remarks on planetary latitudes contained in the LRT. The latter text offers no single comprehensive discussion of this subject, but addresses each planet's motion in latitude separately as part of its overall account of the respective planet (p. 94, l. 30; p. 101, ll. 10–19; p. 102, ll. 6–20; p. 104, ll. 18–33; p. 109, ll. 6–18; p. 116, l. 11–p. 117, l. 5; p. 118, ll. 19–26; p. 120, ll. 21–30; p. 121, l. 32–p. 122, l. 27; p. 123, ll. 22–33). The LRT and III.vi agree terminologically insofar as they both draw on the expression 'head and tail [of the Dragon]', which is common in Islamic astronomy, to designate the ascending (*caput*) and descending node (*cauda*) of a planet. One should also note that the LRT repeatedly mentions that the Moon and five planets each have "a circle similar to the circle of the firmament" (p. 98, l. 10: *similem circulo firmamenti*; see also

p. 101, l. 10; p. 102, l. 18; p. 104, l. 17; p. 109, l. 6; p. 120, ll. 32–33), which resembles the beginning of III.vi (l. 817).

Another clear point of convergence between these texts—and also between them and the *Tractatus magistri Habrahe de tabulis planetarum* (*L*, fols. 58^va^–60^ra^) and *ʿOlam* III (§1:1.8, p. 244)—is their use of 'left' (*sinister*) and 'right' (*dexter*) to refer to the northern and southern parts of the inclined deferent with respect to the ecliptic (LRT, p. 84, l. 13; p. 94, l. 30; p. 101, l. 17; p. 104, ll. 22–25; p. 109, ll. 12–15; p. 116, ll. 20–25; p. 118, ll. 22–23; p. 120, ll. 26–27; p. 121, l. 33; p. 122, ll. 16, 20). *Ptolomeus* and the LRT both use this terminology as a basis to divide the inclined deferent into four sectors, designating these as *sinister ascendens* (ascending node to northern extreme), *sinister descendens* (northern extreme to ascending node), *dexter ascendens* (descending node to southern extreme), *dexter descendens* (southern extreme to ascending node). Our text justifies this use of 'left' and 'right' by stating that "things to the left are above us" and "things to the right below us" (ll. 842–843: *sinistra nobis sunt superiora ... dexteriora sunt nobis inferiora*). It also insists that this way of speaking does not derive from "right or left signs" (l. 834; see also I.iv, ll. 150–151). This remark is intriguing insofar as it finds a parallel in the second version of Ibn Ezra's *Sefer ha-Ṭeʿamim* (*c.* 1154). There he distinguishes between the 'middle', 'left', and 'right' sign of each zodiacal triplicity, again using the terms 'left' (שמאל) and 'right' (ימין) synonymously with 'north' and 'south'.[109]

The LRT makes the important observation that the parlance of a 'left' and 'right' part of the deferent in relation to the nodes only works for the superior planets, whereas the inferior planets have a separate model of latitude. In this model, the inclination of the deferent changes such that the epicyclic centre always remains in the same part with respect to the ecliptic (p. 121, l. 32–p. 122, l. 27). This nuance is absent from III.vi, whose content is therefore applicable only to the latitudinal motions of the Moon and the superior planets.[110]

There are two instances in the LRT where the word *affungion* is used to refer to the northern or 'left' part of a superior planet's deferent (p. 116, ll. 16–18; p. 120, l. 24). In the closely related *Tractatus magistri Habrahe*, the canons for planetary latitudes distinguish between the deferent's *affugion* and *aporion*, which are the halves corresponding to 'left' and 'right'.[111] These terms are clearly related to the *effregion septentrionalis* and *effregion meridiana* mentioned in Plato of Tivoli's translation of al-Battānī's *Ṣābi' Zīj*, which appear to be rooted in Arabic transliterations of the Greek *apogeion*.[112] Variants such as *effregion*, *effengion*, and *effrengion* also appear in the context of the Toledan Tables, many copies of which incorporate the same set of latitude tables as found in the *Ṣābi' Zīj*.[113] Their ultimate origin lies in Ptolemy's *Almagest*.[114]

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[109] *Sefer ha-Ṭeʿamim* II, §2.2:3–6 (ed. and trans. Sela 2007: 186–189).

[110] On the Ptolemaic models and tables for planetary latitude, see Neugebauer 1975: i. 206–226; Pedersen (Olaf) 2011: 355–386; Chabás and Goldstein 2012: 103–104, 106–110.

[111] *L*, fol. 58^vb^: "Deinde si noticia cum qua sumpsisti portionem latitudinis est maior 270 gradibus et minor 360, latitudo est sinistra planete, et similiter a cifre usque 90 gradus. Et illa medietas circuli est affugion. A 90 vero gradibus usque 270 latitudo planete dextra est et semicirculus aporion dicitur." See also ibid., fol. 59^rb–va^.

In *C*'s rendition of III.vi, we are confronted with a similar pairing of *apagon* (northern part) and *apagnon* (southern part) (ll. 843–847, 856–857). It is probably no coincidence that a set of tables for planetary latitudes in MS Berlin, Staatsbibliothek, lat. fol. 307, fol. 28^v, which preserves otherwise unattested parts of the Tables of Pisa (see pp. 19–20 above), uses *apagion* to label the columns for the northern and southern parts of the deferents of the superior planets. This is analogous to the way certain variants of *effregion* are used in other Latin tables and lends support to the idea that the latitude tables in the Berlin manuscript ultimately stem from the same astronomical tables that *Ptolomeus* and the *Tractatus magistri Habrahe* were written to elucidate.

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[112] al-Battānī 1537: fol. 73^v (c. 47).

[113] Pedersen (Fritz) 2002: i. 266 (Ca116); ii. 678 (Cc221); iv. 1322–1326 (FB).

[114] Ptolemy, *Almagest* 13.5 (trans. Toomer 1998: 632–643).

APPENDIX

Description of *C*, fols. 75ᵛ–80ᵛ

Fols. 75ᵛ–76ᵛ

> Circulus augis est superior superficies circuli similis circulo signorum. […] Que equatio ubi in tabulis habetur debet aggregari puncto equato [*interlineary gloss*: id est centro recto], si portio equata [*interlineary gloss*: id est secunda] fuerit minor CLXXX gradibus, vel minui, si maior.

A series of definitions of technical terms relevant to the lunar and planetary equations. The definitions correspond—mostly verbatim—to those in the anonymous *Liber de motibus planetarum*.[1] Also included in this section is an explanation of the minutes of proportion, whose invention is here attributed to "the composers of the Toledan Tables" (*compositores Toletanarum tabularum*), Azarquiel (*Arzacellus*) and *Abenchahant*. This material has no counterpart in the *Liber de motibus planetarum*.

Fols. 76ᵛ–77ᵛ

> Sol et Venus nullam habent portionem sed eandem habent absidem […] Si autem fuit planeta a primo gradu usque in LX erit planeta septentrionis et ascendens, sicut de Sole et Luna dictum est.

A set of canons for planetary longitudes and latitudes, not attested elsewhere. The underlying mean-motion tables were based on the Islamic calendar. Their columns were headed *G*, *P*, and *S*, presumably referring to *gradus*, *puncti/puncta*, and *secunda*. We are notified that year 558 of the Hijri era (= AD 1162/63) began on 9 December, which is indeed correct. The canons are closely related to those preserved in *P*, fols. 2ʳ–3ᵛ (s. XIIᵉˣ), and MS Darmstadt, Universitäts- und Landesbibliothek, 765, fol. 215ʳ⁻ᵛ (longitudes only; s. XIII¹ᐟ²), which belong to an obscure adaptation of the tables of al-Khwārizmī for the Christian calendar and meridian of Toledo.[2] There are significant structural differences between the planetary equation tables in this version and those in the tenth-century recension by Maslama al-Majrīṭī (d. 1007/8), which underlies the better-known Latin translation by Adelard of Bath.[3] It is not unlikely, in fact, that the alternative presentation in the Paris and Darmstadt manuscripts goes back to the lost original version of al-Khwārizmī's *zīj*.[4]

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[1] See *Liber de motibus planetarum* (ed. Nothaft 2018b: 184, ll. 68–71; p. 189, ll. 168–169; p. 190, ll. 178–200; p. 193, ll. 237–243), and the textual comparison in Nothaft 2018b: 156.

[2] See Mercier 1987: 101; Pedersen (Fritz) 2002: iii. 755, 1211 (CE40); iv. 1308 (EC). The rules for planetary latitudes (*P*, fols. 2ᵛᵇ–3ʳᵃ) are very nearly the same as Toledan canons Cc313–315

The rules in *C* are on the whole very similar to those in the two aforementioned manuscripts, but expressed in a different vocabulary, for instance using *apsis* for apogee, *rectitudo* for equation, *centrum* for centre, and *portio* for anomaly. In the other two manuscripts, the corresponding terms are *aux*, *equatio*, *cuspsis*, and *residuum*. The parallels in content as well as the difference in vocabulary between these two versions may be illustrated with the following example:

P, fol. 2^{r}:	*C*, fol. 77^{r}:
Cum volueris equare aliquem trium superiorum planetarum, extrahe medium cursum eius horum trium quem equare volueris de tabulis et pone eum seorsum. Post hec minue medium cursum planete de medio cursu Solis et quod remanserit erit residuum.	Cum autem cuiuslibet trium superiorum, Saturni scilicet, Iovis vel Martis, locum scire volueris, posito prius medio Solis medium stelle suppone. Deinde absidem ipsius stelle. Post hec aufer medium stelle de medio Solis et quod remanserit erit portio una.
Intra cum eo in tabulis numerum equationis residui planete et accipe quod in directo eius inveneris et proice medietatem eius. Post hec aspice residuum. Quod si fuerit minus VI signis, minue ipsam medietatem que erit tibi de auge planete. Et si fuerit ipsum residuum plus VI signis, adde ipsam medietatem super augem planete. Et quod collectum fuerit erit aux equata. Minue eam augem equatam de medio cursu planete et quod remanserit erit cuspis.	Quere eam in ordine numeri et medietatem rectitudinis quam in eius directo inveneris ei subscribe et subscripta absidi adiunge, si portio predicta maior CLXXX fuerit. Si minor, minue. Et quod accreverit vel remanserit erit absis recta. Que de medio cursu stelle detracta facit centrum mediatum.

(ed. Pedersen (Fritz) 2002: ii. 716–718), but this does not justify the conflation of the two texts in Samsó 2020: 688.

[3] For this translation, see the Suter 1914 (edition); Neugebauer 1962 (English translation and commentary); Mercier 1987: 88–100.

[4] See the pertinent comment in Mercier 1987: 101.

Intra cum ea in lineis numerum equationis cuspidis et accipe quod in directo eius inveneris de equatione. Post hoc aspice cuspidem. Que si fuerit minor VI signis, minue equationem quam invenisti de cuspide et adde eam super residuum. Et si fuerit cuspis maior VI signis, adde equationem super cuspidem et minue eam de residuo; equataque erunt residuum et cuspis.	Cuius rectitudine sumpta, si centrum maius CLXXX fuerit, adiungetur centro et minuetur a portione eadem rectitudo. Si vero minus fuerit, demetur ab ipso centro et adiungetur portioni prime. Et erit alterum centrum rectum, alterum portio.
Post hoc intra cum residuo equato in tabulis numeri equationis residui planete et accipe quod in directo eius inveneris de equatione. Postea aspice residuum equatum. Quod si fuerit minus VI signis, adde equationem que erit tibi super cuspidem e⟨quatam⟩. Et si fuerit plus VI signis, minue equationem de cuspide e⟨quata⟩. Eritque cuspis equata bis. Deinde adde augem equatam super cuspidem planete bis equatam. Et quod collectum fuerit erit locus planete, si Deus voluerit.	Secunda cuius rectitudine sumpta, si portio secunda minor CLXXX fuerit, adiungetur ipsa rectitudo centro recto. Si maior, minuetur. Ad aucto sive diminuto centro adiungetur absis recta et erit locus stelle, si Deus voluerit.

This may suggest that we are dealing with two independent translations of the same Arabic source. It is worth noting, however, that the equation tables in the Paris manuscript (fols. 9^{v}–11^{r}) come with two sets of headings, of which one reproduces terms used in *C*.

The text in *C* begins with two lists of apogeal longitudes. One of these corresponds to the standard set of apogees transmitted alongside the Toledan Tables and may be presumed germane to the following canons.[5] The other seems extraneous to the text and may instead be connected to the Tables of Pisa. As the comparison in Table 4 shows, some of the values in this list are close to those in a table of apogeal values for AD 1100, which was linked to an annual precession rate of 0;0,51° familiar to the works of Ibn Ezra. It apparently accompanied the Tables of Winchester, which in turn were based on the Tables of Pisa.[6]

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[5] See Pedersen (Fritz) 2002: iii. 1222–1225 (DA).

[6] See Pedersen (Fritz) 2002: iii. 1226–1227 (DB21), and pp. 141–142 above.

TABLE 4 Apogeal longitudes for the Sun and five planets in *C* compared with Abraham Ibn Ezra's (?) values for 1100

	Sun/Venus	**Saturn**	**Jupiter**	**Mars**	**Mercury**
C, fol. 76^v	86;15°	217;10°	171;32°	128;24°	205;10°
1100	86;14°°	250;10°	172;40°	130;12°	205;11°

Fols. 77^v–78^r

> Cum autem alicuius V planetarum latitudo […] Veneris et Mercurii in utraque parte equaliter.

An excerpt from the Toledan canons *Scito quod annus lunaris*, dealing with tables of planetary latitude.[7] This excerpt begins in the 7th line from the bottom of fol. 77^v immediately after the end of the previous text, with no indication of any break.

Fol. 78^r

> Medius cursus Saturni II minuta. Iovis V. Martis XXXI. Solis LVIIII, qui numerus etiam tenendus est in Venere et Mercurio.

A generic note on planetary mean motions.

Fol. 78^r

> Latitudo lune est V gradum ex gradibus circuli signorum. Tantum, id est V gradibus, declinat ab eo.

A note on the inclination of the lunar deferent.

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[7] *Ca* 116–122 in Pedersen (Fritz) 2002: i. 266–270.

Fol. 78r

> Draco dicitur figura que accidit de compositione circuli planetarum et circuli Solis […] Alter vero dicitura cauda, sive oppositum.

A text explaining the basic concept of the ascending and descending node or 'head and tail of the Dragon'.

Fol. 78r–v

> Geuzaar Lune non consistit semper nec invenitur eodem loco […]. Mercurii CCLXX g⟨radus⟩ III m⟨inuta⟩.

Notes on the motions and locations of the planetary nodes (*geuzaar*). Discounting some scribal errors, the positions of the ascending nodes agree with the values known from the Toledan Tables.[8] The rate of precession is here taken to be 1°/100y (Ptolemaic).

Fol. 78v

> Sol et Mercurius sunt valde amici, ideo scilicet quia Mercurius est velut vernacula obediens Soli […] Saturnus non timet Martem.

A note on planetary relationships derived (with small alterations) from the *Proportiones competentes in astrorum industria*, a text in the *Alchandreana* corpus.[9] Placed below it is a schematic horoscope chart that shows each planet (except the Moon) in a different house/sign, perhaps to indicate its respective domicile.[10] This seems to be confirmed by the positions of Saturn, Jupiter, and Mercury, which are each shown in one of their accustomed domiciles (Aquarius, Sagittarius, Gemini). By contrast, the domiciles of Venus (Aries) and Mars (Libra) appear to have been mixed up. Also, the Sun here appears in Virgo rather than Leo.

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[8] See the first set (DC41, 51, 61, 71, 81) in Pedersen (Fritz) 2002: iii. 1230–1233.

[9] See *Proportiones* §§ 6, 7.1–6, 7.13 (ed. Juste 2007: 513).

[10] I owe this interpretation to David Juste.

Fol. 78v

> Prima turris est vite, id est nativitatis seu hominis. […] Duodecima est inimici, asini, equi et omnis bestie que equitatur.

A list of the significations of the twelve houses, which is excerpted from the pseudo-Ptolemaic *Iudicia*.[11]

Fol. 78v

> De annis Arabum [= *heading*]. Annus Arabum incipit in VIIº die Aprilis. Qui semper constat ex 354 diebus annis Arabum secundum rationem XII mensium ipsum perficientium. Quorum primus, videlicet Almuharam, constat ex 30 diebus et Saphar secundus ex 29 et alii omnes sic alternatim prout sibi succedunt.

A note about the Islamic calendar. It is probably datable to AD 1152, when the beginning of the Islamic lunar year fell on 7 April.

Fol. 78v

> Lectio sequentis pagine [= *heading*]. Si vis principia annorum vel mensium Arabum qua scilicet feria ingrediantur per hanc tabulam scire […]. Et ubi terminabitur numerus in ea die vel mensis quesiti vel anni erit erit initium, si Deus voluerit.

A canon for a calendrical table found on the facing page (fol. 79r). The table is for finding the initial day of the week of any year or month in the Islamic lunar calendar. There are sub-tables for months (*Almuharam* to *Dulhega*), expanded years (1 to 30), and collected years (30 to 900). The table in questioned circulated widely as part of the Toledan Tables.[12] Its rendition in *C* seems unusual, however, in that it systematically decreases the numbers in the table for months by one day, while increasing those in the table for expanded years by the same amount.

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[11] Pseudo-Ptolemy, *Iudicia*, § 14, transcription by David Juste available at: https://ptolemaeus.badw.de/ms/60/106/transcription/1. On this source, see David Juste, "Pseudo-Ptolemy, *Iudicia*" (update: 10.03.2022), *Ptolemaeus Arabus et Latinus. Works*, URL = http://ptolemaeus.badw.de/work/63.

[12] See Pedersen (Fritz) 2002: iii. 929–931 (AD11).

Fols. 78^{v}–79^{r}

> Si autem annos Arabum vel eorum principia per annos Here aut Christi scire volueris, minue ex annis Here 660, ex annis Christi 621. […]. Et si remanens fuerit plus 15 et minus 29, erit annus bissextilis. Si vero plus vel minus remanserit, non.

A set of instructions for converting dates in the Julian calendar according to either the *Anno Domini* or the Spanish era into dates in the Islamic calendar. Calendrical conversion rules of this type are not uncommon in canons to astronomical tables. The present example, however, is closely related to the instructions for the same purpose included in the *Sententie de diversis libris excerpte*, a type of commentary or introduction to the Toledan Tables written by John of Spain (or John of Seville), which survives incompletely in two manuscripts.[13] The hypothesis that the text in *C* has been derived in some way from the *Sententie* is supported by several close verbal correspondences, which are italicized in the right-hand column of the following comparison:

Sententie (ed. Millás Vallicrosa 1936: 463; corrected against Madrid, Biblioteca Nacional de España, 10053, fol. 87^{ra}):	*C*, fol. 78^{v}:
Postquam scivieris annos ere et minueris ex eis DCLX, ut supradictum, multiplicabis reliquos in ĪĪXↃCXV [sc. 21915] et diuides quod collectum fuerit per ĪĪCCLXII et quod exierit erunt anni arabum perfecti, quod vero remanserit iterum divide per LX et quot diuisiones exierint tot dies erunt super quod debes addere dies CLXXI, addes quoque et dies qui transierunt de anno in quo fueris a kalendis ianuarii, et si collectum fuerit ex istis diebus plus CCCLIIII, fac de illis CCCLIIII unum annum lunarem et adde eum super annos.	Minue ex annis here 660 […] et reliquum multiplica per 21915 *et divide quod collectum fuerit per 21262 et quod exierit erunt anni arabum perfecti. Quod vero remanserit iterum divide per 60 et quot divisiones extiterint tot dies erunt super quos debes addere 171. Addes quoque et dies qui transierunt de anno in quo fueris a kalendis ianuarii et si ex his diebus plus 354 collegeris ex 354 unum annum lunarem fac et adde eum super annos.*

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[13] The text was edited in Millás Vallicrosa 1936: 459–475. It is preserved, incompletely it seems, in MS Madrid, Biblioteca Nacional de España, 10053, fols. 86^{va}–88^{va} (s. $\text{XIII}^{2/2}$). Two fragments from the introduction are found in MS Oxford, St John's College, 188, fols. 102^{r}, 104^{va} (s. XIII/XIV). The former manuscript renders the author's name as *Iohannes Ispanus*, the latter as *Iohannes Yspalensis*. For discussions of the text and its authorship (which is uncertain), see Millás Vallicrosa 1936: 453–459; 1942: 196–197; 1943–1950: 368–372; Pedersen (Fritz) 2002: i. 194–195; iii. 756; Burnett 2002b: 63–66; Robinson 2007: 64–69 (unreliable); Hasse 2016: 30.

Sententie (ed. Millás Vallicrosa 1936: 464; corrected against Madrid, Biblioteca Nacional de España, 10053, fol. 87^{ra}–b):

Cur autem minuis predictos annos de era vel cur addis super multiplicationem annorum dies CLXXI uel minuis in alia regula CXCV, prudentia tua debet intelligere quia transactis de era DCLVIIII annis et CLXV diebus DCLX anni transacto scilicet XIIII die mensis iulii sumpserunt initium predicti anni arabum et quia non possumus multiplicare dies cum annis integris, ideo peracta multiplicatione addimus dies si ceperimus multiplicare ab inicio DCLXVI anni uel minuimus si ceperimus ab inicio anni DCLX, et hoc sit ad placidum operantis. Et in hiis omnibus si inueneris aliquem diem qui tibi uideatur quasi superfluus, nec te seducat nec conturbet, quia de fractionibus surget id est de quarta diei que additur in omni anno solari, et de quinta et de sexta diei que similiter additur in omni anno lunari.

C, fols. 78^{v}–79^{r}:

Cum autem predictos annos de annis ere vel Christi minuis vel *addis super multiplicationem annorum dies 171*, hoc ideo facis, *quia transactis de* annis ere 670 *annis et 165 diebus* 14^{mo} *scilicet die mensis iulii sumpserunt inicium anni arabum.* Annis autem Christi 621 existentibus et diebus similiter 165 eadem die eiusdem mensis qui a medio sui incipiunt cum dies cum dies Arabum a medio diei precedentis incipiant. Dies autem cum *annis multiplicare non possumus*, sed *peracta multiplicatione addimus dies, si ceperimus ab inicio* perfectorum, *vel minuimus, si ceperimus ab inicio* imperfectorum, *et hoc sit* secundum nostrum libitum. *Et in his omnibus si invener*imus *aliquem diem qui quasi videatur superfluus*, non inde *turbe*mur, *quia* sunt *de fractionibus de quarta* scilicet *diei que additur in omni anno solari et quinta et sexta diei, que additur in omni anno lunari.* Unde bissextus efficitur.

Fol. 79^{r}

> Lectio sequentis tabule [= *heading*]. Nota quod quidam astrologi volunt planetas et eorum absides et ceteras stellas omnes secundum motum circuli signorum moveri et per 100 annos ambulare […] Secundum Albatheni in 66 annis unum gradum et unum minutum secundum cuius summam tabula facta est per quam scitur an eant ante an retro.

A canon for a precession table copied overleaf (fol. 79^{v}). It mentions Ptolemy, al-Khwārizmī (*Algoarismus*), Abū Maʿshar (*Abymasar*), and al-Battānī. There are once again significant overlaps with the *Sententie de diversis libris excerpte*:

Sententie (ed. Millás Vallicrosa 1936: 467):
Sunt enim multi astrologi qui putant omnes planetas et auges eorum ac ceteras stellas fixas per motum circuli signorum moueri, et a pristinis locis recederet et per C annos unum gradum ambulare et sic per successiones signorum, ita ut in XXXVI milibus annorum uerteretur semel et hic erat motus octaui circuli, circuli scilicet signorum, apud antiquos. Moderni autem dicunt quod predictus circulus accedat et recedat, id est quod erat ante per VIII gradus et iterum reuertatur retro.

C, fol. 79^r:
Nota quod quidam astrologi volunt *planetas et eorum* absides et *ceteras stellarum* omnes secundum *motum circuli signorum moveri et per 100 annos ambulare per successiones signorum, ita ut in 36000 annorum verterentur semel.* Et hoc dicebant motum octave spere. *Moderni autem dicunt quod predict*a spera *accedat et recedat, id est quod eat ante per 8 gradus* vel per 10 *et iterum revertatur retro*, in 100 annis unum gradum secundum Ptholomeum.

The corresponding table appears on fol. 79^v. It is based on the Syriac version of the Julian calendar, with a beginning of the year in Adhar/March, and consists of sub-table for days (1 to 30), months (*Adar* to *Subath*), years (1 to 20), and collected years (20 to 260). The are no headings, although the implied annual rate of motion of *c.* 0;0,54,33° (3;1,49° in 200 years) confirms that we are dealing with a precession table. Another copy, with headings mentioning the *motus stellarum fixarum*, is transmitted in MS Cambridge, Gonville & Caius College, 456/394, p. 139 (s. XIII^{in}).[14] These tables are in fact a faithful Latin rendering of the precession tables in al-Battānī's *Ṣābi' Zīj*,[15] which raises the possibility that they stem from a twelfth-century translation of the whole work. The extant translation by Plato of Tivoli only covers the accompanying treatise or canons.[16] Another translation was reportedly made by Robert of Ketton, but there is no further evidence of its survival.[17]

Fol. 79^r

Si volueris scire si mundus sit in directione an in retrogradatione adde super annos Iadazar regis Persarum 288 et divide quod collectum fuerit per 640. [...] Aliter enim nec loca planetarum certissime invenies nec eclipsis tempora nec arcus diei nec noctis quantitatem nec stellarum fixarum quantitates.

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[14] See Nothaft 2017c: 73.

[15] Nallino 1899–1907: ii. 107.

[16] See on this translation Lejbowicz 2009.

[17] It is mentioned in Hermannn of Carinthia's 1143 translation of Ptolemy's *Planisphaerium*. See Heiberg 1907: clxxxvii; Burnett 1978: 112; Mercier 1987: 113.

This passage is connected with the preceding canon for al-Battānī's precession table. It describes an algorithm for a model of 'trepidation', where precession advances at a rate of 1°/80y and reverses direction every 640 years. It is derived from the *Sententie de diversis libris excerpte*, which in turn quote from Abū Maʿshar's *On the Great Conjunctions*.[18]

Sententie (ed. Millás Vallicrosa 1936: 468):	*C*, fol. 79$^{\text{r}}$:
Cum uolueris scire motus accessionis et recessionis adde super annos iadagyrd annos perfectos DCCLXXXVIIII et diuide quod collectum fuerit per DCX[L] et aspice quod exierit de diuisione et proiece illud unum, unum, et incipe per retrogradationem circuli, deinde per rectitudinem eius.	Si *volueris scire* si mundus sit in directione an in retrogradatione *adde super annos iadazar* regis Persarum 288 [*sic*] et *divide quod collectum fuerit per 640 et quod exierit* partire *per retrogradationem* ac directionem, incipiens inde ac inde proficiscens.

Fol. 79$^{\text{r–v}}$

> Scientia equationis et recessionis circuli, ut verificetur per hoc altitudo planetarum in medio diei […]. Et quod fuerit erit quantitas accessionis et recessionis quam debes addere vel minuere super loca planetarum et stellarum quemadmodum supra diximus.

This is a rule for computing the so-called access and recess of the eighth sphere, which belongs to a set of canons for the Toledan Tables.[19]

Fol. 80$^{\text{r}}$

The whole page is taken up with tabular list of intervals, in Julian years, months, days, and hours, between different eras commonly used in astronomical texts and tables (eras of Nabonassar, Alexander [= Seleucid era], the death of Alexander, Christ, Yazdegerd) as well as between these eras and vernal equinox observations attributed to Hipparchus, Ptolemy, and Thābit ibn Qurra. The equinox times given in the latter two cases

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[18] Abū Maʿshar, *On the Great Conjunctions* 2.8.37 (ed. and trans. Yamamoto and Burnett 2000: i. 154–155).

[19] Cc235–236 in Pedersen (Fritz) 2002: ii. 686.

(22 March 140, 2h after noon, and 17 March 813, 4h before sunrise) correspond to those cited in the *Compotus* of Master Cunestabulus (1175).[20] A note at the bottom, concerning the time of the vernal equinox of 13 March 1392 at Jerusalem, was excerpted from the same source.[21]

Fol. 80^{v}

This page shows a calendrical table that correlates the beginning of the Islamic lunar year with the Julian calendar over a period of 30 years. The dates in question range from 21 July 1175 (Hijri year 571) to 9 September 1203 (Hijri year 600). Added to these dates are the corresponding ferial number (indicating the day of the week) and the concurrent of the Julian year. The years 1175 and 571 of the *Anno Domini* and Hijri eras are mentioned in a heading. The right margin contains notes listing the dates and days of the week of some of the epochs used on fol. 80^{v}. Further notes placed above the table mention: (a) the value for the access and recess of the eighth sphere in the present year (presumably 1175) as 8;20°; (b) the date of the solstice as 17 January [*sic*], 45 seconds after noon on the meridian of Toledo.

A note in the left margin states that the true vernal equinox *in hoc anno* occurred on 13 March, 3 equinoctial hours and 2 moments (= 0;3h) before midnight on the meridian of Jerusalem. The corresponding mean equinox occurred on 17 March, 1 equinoctial hour, 876 *partes*, and 16 *particula* after midnight.[22] The notation used for the mean equinox is clearly related to the calculation of the *tequfot* (equinoxes and solstices) in the Jewish calendar according to the system attributed to Rav Ada, where the hour is divided into 1080 *ḥalakim*, each of which contains 76 *regaim*.[23] In 1175, the vernal equinox according to this system fell on 17 March, 1 hour, 754 ḥalakim, and 16 regaim after noon. It therefore seems reasonable to suggest that the 876 parts mentioned in the text are somehow a mistake for 754 and that the epoch used in the calculation was shifted by 12 hours. One should note that familiarity with the Jewish calendar is also a trait of the aforementioned *Compotus* of Cunestabulus, which dates from the same year 1175.[24]

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[20] Cunestabulus, *Computus* 36 (ed. Lohr 2015: 109, ll. 106–114).

[21] *C*, fol. 80^{r}: "Anno 1392 ab incarnatione domini III^{o} idus Martii equinoctium vernum post meridiem Iherosolime fere II^{bus} [*sic*] momentis. Postmodum revertetur ad datas sequentes. Ab Helligera capite Arietis anni Arabum 794, Romanorum 771." The first sentence corresponds to Cunestabulus, *Computus* 36 (ed. Lohr 2015: 109, ll. 148–151). The time of the vernal equinox is here 8 moments after noon.

[22] *C*, fol. 80^{v}: "In hoc anno vernum equinoctium equatum secundum equationem IIIbus horis equalibus equatis et duobus momentis ante mediam noctem Iherosolime quam noctem sequitur II idus Martiarum secundum medium cursum in una hora equali, 800tis et 76 partibus et 16 particulis post mediam noctem Iherusalem quam sequitur XVI kl. Aprilis."

[23] See Nothaft 2014a: 31–32.

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[24] See Nothaft 2014a: 66–67; 2018c: 89–90.

PART 2

Robert of Chester, Liber Canonum*, pt. II: Tables of London*

⁖

Introduction

Past accounts of Robert of Chester (*fl.*1144–1150) and his contributions to the twelfth-century 'movement' of translating scientific texts from Arabic into Latin have been marked by a tendency to treat him as identical with Robert of Ketton, the famous translator of the Quran.[1] While the two Roberts were almost exact contemporaries and known by similar sounding toponyms, *Cestrensis* and *Ketensis*, the evidence of their known works lends insufficient support to the opinion that they were indeed one and the same. As Charles Burnett points out in the *Oxford Dictionary of National Biography*, the extant material even suggests two different biographical itineraries. Robert of Ketton was archdeacon of Pamplona and transitioned from his activities as a scholar and Arabic-to-Latin translator to an active ecclesiastical-political life in Navarre. Robert of Chester, by contrast, appears to have been in Spain only briefly before returning to his native England, where he continued his work as a scientific writer and translator.[2]

The question of the identity of the two Roberts is a difficult one and will not be pursued any further in the present study. What is clear is that *Robertus Cestrensis* makes his first documented appearance as the translator of the *Liber Morieni*, which carries the distinction of being the first known rendering of an alchemical work into Latin. Manuscript colophons indicate that Robert finished this translation on 11 February 1144, without giving information about his location.[3] He was certainly in Spain in 1145, the year in which he completed the first Latin translation of a work on algebra, al-Khwārizmī's *Liber Algebre et Almuchabolae*. Text-internal evidence locates him in Segovia in the kingdom of Castile.[4] His next datable production is the pseudo-Ptolemaic *Liber de compositione universalis astrolabii*, whose manuscripts proclaim that Robert translated the text from Arabic into Latin to London in year 1185 of the Spanish era, or AD 1147. Ptolemaic authorship can be excluded on the grounds that the type of universal astrolabe the text describes was only designed in the eleventh century by ʿAlī ibn Khalaf, an Andalusian astronomer.[5] Even the text's status as an Arabic-to-Latin translation has been called into question on the basis that its vocabulary appears to depend on previous Latin texts on the astrolabe.[6]

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[1] See, e.g., Steinschneider 1871: 392–393; 1904: 67–73 (no. 102); Archer 1896; Karpinski 1915: 25–32; Haskins 1915: 61–65 = 1924: 120–123; Sarton 1927–1948: ii. 175–177; Lemay 1963: 654; 1990–1991; Kritzeck 1964: 62–65; Metlitzki 1977: 30–35; Busard and Folkerts 1992: i. 22–31; Brentjes 2000: 283–284; de la Cruz Palma and Ferrero Hernández 2011.

[2] Burnett 2004; Hasse 2006: 69. See previously already Southern 1992: xlvii–xlix.

[3] Lemay 1990–1991.

[4] The translation was edited by Hughes 1989. A previous edition and English translation was published by Karpinski 1915.

Another Andalusian astronomer of the eleventh century, Ibn al-Ṣaffār (d. 1035), may be counted among the probable influences on Robert's *Liber de officio astrolabii*, which consists of 36 chapters explaining the manifold uses of the standard planispheric astrolabe. Although the text has only come down to us in two fifteenth-century copies,[7] the attribution to Robert of Chester receives strong support from its penultimate chapter, where the author references his *Liber canonum* for the cities of Toledo and London.

> De ratione coequationis 12 domorum in libro canonum que [sic] super Toletum et civitatem Londoniarum edidimus, prout tractatus exposcebat ratio, tractavimus. Unde in hoc libro qualiter ipse inveniantur per astrolabium docere curabimus.[8]

> In the book of canons that we composed for Toledo and the city of London, we dealt with how to equate the twelve houses according to what was demanded by the method of the treatise [in question]. In the present book, we accordingly shall make sure to teach how these [houses] are found with an astrolabe.

The second part of this *Liber canonum*, or book of "canons" (here meaning astronomical tables), survives as a work by Robert of Chester in two manuscripts of the thirteenth and fourteenth centuries. Additionally, fragments or excerpts of differing length can be found in at least four other manuscripts. Apart from a handful of passages quoted by Fritz Saaby Pedersen in 1990, the text has never been printed in any shape or form,[9] nor has it been the subject of an in-depth study.[10] As a consequence of this neglect, there are fundamental questions about its date, content, and sources that still await a substantive answer. The following pages aim to close some of these gaps in our knowledge, by making the surviving textual remnants of the *Liber canonum* available to future scholarship and supplementing them with a section-by-section commentary as well as an introductory study setting out their sources, content, and transmission.

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[5] Edited by David Juste, "Transcription of Pseudo-Ptolemy, *Liber de compositione universalis astrolabii*" (update 09.06.2021), *Ptolemaeus Arabus et Latinus. Texts*, URL = https://ptolemaeus.badw.de/text/M338. For further information and a full list of manuscripts, see Juste, "Pseudo-Ptolemy, *Liber de compositione universalis astrolabii*" (update: 12.01.2022), *Ptolemaeus Arabus et Latinus. Works*, URL = http://ptolemaeus.badw.de/work/55.

[6] Kunitzsch 1982: 489–491.

[7] MSS Milano, Biblioteca Ambrosiana, H 109 sup., fols. 9v–17v (pages missing; s. XV); Oxford, Bodleian Library, Canon. misc. 61, fols. 12r–22v (s. XV). See Kunitzsch 1982: 492. This text must be distinguished from one with the incipit "Cum plurimi ob nimiam quandoque accurtationem …," which is a fifteen-century composition on the astrolabe by Christian of Prachatice (see Hadrava and Hadravová 2017) that was printed in 1477–1479 as a work by Robert the Englishman (*Robertus Anglicus*). Thorndike (1943: 467n1) conflates this text with the one in the Oxford manuscript.

[8] MS Milano, Biblioteca Ambrosiana, H 109 sup., fol. 17r (c. 35). Attention to this passage was first drawn by Haskins 1915: 64 = 1924: 123. See also Mercier 1987: 109; 1991: 19.

1 Sources and General Characteristics

The second part of Robert of Chester's *Liber canonum*, a text beginning *Promissa vero electe facultatis …*, has as its main witnesses two manuscripts now in Oxford (*A* and *S*). Both come with headings identifying the author as *Robertus Cestrensis* and the text as "the other part of this work" (*pars altera huius operis*), which was "composed for the meridian of the city of London" (*que videlicet ad meridiem urbis Londoniarum* […] *contexitur*). In the above-cited passage from the *Liber de officio astrolabii*, Robert refers to a book containing "canons" for Toledo and London, which suggests that he used the Greek loan word *canon* as a synonym for 'numerical/computational table'. This is indeed confirmed throughout the text at hand, which begins with Robert mentioning the "method of the canons" (l. 7: *ratio canonum*) and how to use such "canons" to find the positions of the planets (ll. 7–8: *per canones … inventio locorum planetarum*). The same manner of speaking existed in Greek astronomy, as exemplified by Ptolemy's *Handy Tables* (*Πρόχειροι κανόνες*). Latin instructions for their use were available in the twelfth century under the title *Preceptum canonis Ptolomei*, which may have played a part in motivating Robert's use of the word *canon*.[11] Rather than following this precedent, later Latin astronomers tended to use *canon* in the sense of 'rule', applying it not to the tables themselves but to written instructions for their use, as were also included in Robert's work.[12]

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[9] Pedersen (Fritz) 1990: 212–213, 217. These excerpts are taken from *Lc*12, *Lc*19, and *Lc*16–18.

[10] The most substantial discussions published to date are those in Mercier 1987: 109; 1991: 17–19. Other mentions include Steinschneider 1871: 392; 1904: 68–69; Nallino 1899–1907: i. xxxiv–xxxv; Haskins 1915: 64 = 1924: 122–123; Karpinski 1915: 29; Duhem 1915: 519–520; Millás Vallicrosa 1943–1950: 372; Lipton 1978: 168–169, 208; Richter-Bernburg 1987: 375, 392 (n. 9c); Pedersen (Fritz) 1990: 211; 2002: iii. 756.

[11] See Pingree 1997; David Juste, "Ptolemy, *Preceptum canonis Ptolomei* (tr. before c. 1000)" (update: 17.05.2022), *Ptolemaeus Arabus et Latinus. Works*, URL = http://ptolemaeus.badw.de/work/52.

In what follows, I am going to reserve the title *Liber canonum* for the complete work for Toledo and London mentioned in the astrolabe treatise, while shortening it to *Lc* when referring specifically to the extant chapters of the second part. Numbers added to *Lc* will be used to indicate specific chapters/sections in the edition below. The first part of the *Liber canonum* must be presumed lost. From the indications given in *Lc*, it appears that it contained a Christian adaptation of the so-called Toledan Tables, an influential *zīj* that originated in the eponymous Iberian city in the second half of the eleventh century. In the adaptation included in the *Liber canonum*, the Toledan mean-motion tables were recast for the Julian calendar and Christian era (see § 5). Their initial epoch or starting date was set at 1 January AD 1149 (*Lc*4, l. 273), whereas the London tables in *Lc* had an initial epoch of 1 March AD 1150 (*Lc*1, ll. 9–27, 105–107; *Lc*4, ll. 275–277). Given the proximity between these two epochs, it seems reasonable to suppose that they were both chosen for being close to the time of composition.[13] This hypothesis is fairly consistent with the dates that can be assigned to other known works and translations by Robert of Chester, which show that he was active in the years 1144–1147.

Robert's mean-motion tables for London were an adaptation of the Tables of Pisa by Abraham Ibn Ezra, which had in turn been derived from a *zīj* by the tenth-century Persian astronomer al-Ṣūfī (see § 4 below and § 2 in part I). They differed from the Toledo tables of the *Liber canonum*'s lost first part in displaying tropical rather than sidereal coordinates and also in certain structural details, such as the use of 20-year rather than 28-year periods of 'collected years'. In the two Oxford copies of *Lc*, *A* and *S*, the only tables included in the text are tables for the precession of the solar apogee (*Lc*8) and the hourly velocities of the Sun and Moon (*Lc*14). Fortunately, however, most of the other tables mentioned in *Lc* have survived elsewhere. The single most important witness to them is a London manuscript (*L*), where the tables in question appear next to certain extracts from *Lc*.

According to the general heading transmitted in manuscripts *AS* and Robert's own words in *Lc*1 (ll. 1–8), his Tables of London were in some sense based on or representative of the teaching, principle, or doctrine (*doctrina*) espoused by one *Albaten Haracensis*. This is no doubt a reference to Abū ʿAbd

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[12] See, for example, the various headings used for canons 'Cb' to the Toledan Tables: Pedersen (Fritz) 2002: ii. 333–334.

[13] Other scholars have suggested a date of composition in 1170. See p. 313 below.

Allāh Muḥammad ibn Jābir ibn Sinān al-Battānī (d. 929), who computed astronomical tables for the meridian of his hometown of ar-Raqqah in Syria (hence *Haracensis*).[14] It is nevertheless unclear what Robert meant to signify when he wrote that the Tables of London made it possible to find planetary positions "according to" this astronomer's "teaching" or "doctrine" (l. 8: *iuxta Albatem Haracensis doctrinam*). If he considered the Tables of London to be an adaptation of al-Battānī's work, known as the *Ṣābiʾ Zīj*, this would entail that he was ignorant of the actual origin of his mean-motion tables.[15] It may well be, however, that the "doctrine" of al-Battānī was supposed to denote something more general, such as the structural principles of the tables in question. Robert's claim could here find justification in the fact that al-Battānī had founded his mean-motion tables on the Julian calendar, starting each year on 1 Adhar = 1 March and counting 20-year intervals of collected years, which are structural features shared by the Tables of London.[16]

A further point of convergence between al-Battānī's tables and the Tables of London is their reliance on a tropical year, which set them apart from the sidereal reference frame used in the Toledan Tables. While it is possible that Robert was to some extent oblivious to this specific aspect, he was certainly aware that al-Battānī had made the apogees of the Sun and five planets move with the rate of precession, whereas other tables (i.e., sidereal ones) treated them as immobile. He discusses the matter in *Lc*8, which in the extant manuscripts always incorporates a set of tables for the motion of the solar apogee. The parameter underlying these tables, 0;0,54°/y, is a rounded version of al-Battānī's original value for the rate of precession (1°/66y = 0;0,54,32,43…°/y). It seems probable, moreover, that the set of apogeal longitudes for 1 March 1150 transmitted alongside the Tables of London was ultimately derived from the longitudes listed in the *Ṣābiʾ Zīj* (see § 4).

If and how Robert was able to access this *zīj* remains a matter of speculation. By the time he composed the *Liber canonum*, a translation of the work had already been undertaken by Plato of Tivoli (*fl.*1130–1145), who was based in Barcelona. The extant copies of this translation, however, are restricted to the textual part of the *Ṣābiʾ Zīj*, leaving no definite evidence that Plato ever included the tables themselves.[17] An allusion to what appears to have been a second Latin rendering of the *Ṣābiʾ Zīj* is contained in Hermann of Carinthia's translation of Ptolemy's *Planisphaerium* (1143), where Hermann seems to credits his friend and collaborator Robert of Ketton with translating some work by al-Battānī.[18] This passage would carry added significance if Robert of Ketton and Robert of Chester could be shown to have been one and the same person, which remains doubtful.[19]

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[14] See Nallino 1899–1907; van Dalen and Pedersen 2008; Chabás 2019: 39–44.

[15] This was the conclusion drawn by Mercier 1991: 18.

[16] For al-Battānī's mean-motion tables, see Nallino 1899–1907: ii. 72–77, 102–106.

[17] On this translation, see Lejbowicz 2009.

A definite hint that at least some of the tables in al-Battānī's *zīj* found their way into Latin during the twelfth century comes from two stand-alone copies of his precession tables, which may have been excerpted from a larger set.[20] In addition, Latin astronomers of the twelfth and later centuries had indirect access to many of al-Battānī's tables via the Toledan Tables, whose contents were heavily derivative of the *Ṣābiʾ Zīj*. Apart from his including a Christian adaptation of these tables in the lost first part of the *Liber canonum*, Robert also appears to have drawn on the Toledan Tables for the equation tables included among his Tables of London, whose parameters go back to al-Battānī.[21] Another 'Battānīan' table in Robert's work is the table for the hourly velocities of the Sun and Moon in *Lc*14. As with the equation tables, parsimony would seem to dictate that the table in question came to him via the Toledan Tables rather than directly from al-Battānī's work.[22]

Aside from being indebted to Abraham Ibn Ezra and al-Battānī, the *Lc* contains traces of an Indian astronomical tradition that had become available in Latin Europe via the ninth-century *Sindhind Zīj* of al-Khwārizmī.[23] Robert knew these tables from a translation by his fellow Englishman Adelard of Bath, who had used an Andalusian recension of the original *zīj* that incorporated revisions by Maslama al-Majrīṭī (d. 1007/8) and one of his students, the aforementioned Ibn al-Ṣaffār (d. 1035). A clear sign of its influence on *Lc* are the chapters on planetary latitudes (*Lc*21) and stations/retrogradations (*Lc*22–23). In writing these chapters, Robert may have relied on his own revision of Adelard of Bath's translation, which survives in a thirteenth-century manuscript now in Madrid.[24] Some of the mean-motion tables in this recension come with added notes specifying additions to the radices in the collected-year tables that would have to be made to adjust them to the meridian of London.[25] Owing to the loss of multiple pages from the Madrid manuscript, it is no longer possible to compare the borrowings from the Khwārizmīan canons visible in *Lc*21–23 with Robert's own revision of these canons. As a result, the relative chronology of the revision of al-Khwārizmī and the writing of *Lc* is in doubt. The idea that the *Lc* drew on the revision is not necessarily at odds with the presence of a gloss in the Madrid manuscript, which the scribe of the main text added to a canon describing the Julian year (*M*, fol. 8^{va}):

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[18] Burnett 1978: 112: "[…] quem locum a Ptolomeo minus diligenter perspectum cum Albeteni miratur et Alchoarismus, quorum hunc quidem opera nostra Latium habet, illius vero comodissima translatione studiosissimi Roberti mei industria Latine orationis thesaurum accumulat, nos discutiendi veri in libro nostro de circulis rationem damus." The passage is also quoted in Heiberg 1907: clxxxvii; Nallino 1899–1907: i. xlix–l. Hermann of Carinthia was clearly familiar with al-Battānī's work, as is shown by Burnett 1982: 30. See also the discussion in Mercier 1987: 113.

[19] The suggestion that Robert used his own translation of al-Battānī when he cast the Tables of London was made in Pedersen (Olaf) 1975: 70.

[20] See MSS *C*, fol. 79^{v} (s. XII$^{4/4}$); Cambridge, Gonville & Caius College, 456/394, p. 139 (s. XIII^{in}).

[21] See n. 57.

[22] See n. 58.

[23] On the content, transmission, and reception of this *zīj*, see Mercier 1987: 88–102; Pingree 1996; King and Samsó 2001: 31–35, 56–57; Chabás and Goldstein 2015: 580–584; van Dalen 2018; Chabás 2019: 34–39; Samsó 2020: 688–702.

> Nota quia secundum librum canonum non peragit Sol singulis annis cursum suum; deest enim quantum ipse progreditur dum tres gradus et duo minuta circuli extimi oriuntur. Que collecta annis quidem CXX diem et paxillum diei exigunt.
>
> Note that according to the *Liber canonum* the Sun does not complete its course every year, since there is a shortfall that is as large as its motion while three degrees and two minutes of the outermost circle are rising. If these are added together over 120 years, they amount to one day and a small fraction of a day.

The unusual expression *paxillum diei* to indicate a small fraction of time also occurs in *Lc*1 (l. 33), which would seem to confirm that the *Liber canonum* mentioned in this gloss is the one Robert composed for tables for Toledo and London. As with the reference in his *Liber de officio astrolabii* to a passage on domification, however, the content mentioned here does not match the preserved chapters. What *Lc*1 states is that a solar year lasts 365 ¼ days + 1/900th of an hour, a fictitious value derived, through faulty arithmetic, from a daily solar motion of 0;59,8° (see pp. 299–300). The aforementioned gloss, by contrast, cites a year length that is practically the same as al-Khwārizmī's sidereal year, which is 365 ¼ + 1/120 days corresponding to an annual rotational excess of 93;2°[26] We have another attestation of this rotational excess in the *Liber de officio astrolabii*, in a chapter that explains how to compute annual revolutions.[27]

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[24] *M*, fols. 8^{ra}–68^{v}. Title: *Incipit liber ezeig, id est chanonum Alchoarizmi per Adelardum Bathoniensem ex Arabico sumptus et per Rodbertum Cestrensem ordine digestus*. See Suter 1914: xi–xx; Haskins 1915: 64–65 = 1924: 123; Bliemetzrieder 1935: 123–125; Mercier 1987: 96–97, 99–100. For descriptions of the manuscript, see Millás Vallicrosa 1942: 247–256; Pedersen (Fritz) 2002: i. 131–132.

[25] *M*, fols. 14^{v}, 18^{v}, 23^{v}, 24^{v}, 28^{v}. Implicit in these additions seems to be the assumption that London is approximately 55° west of al-Khwārizmī's meridian of reference, which is Ujjain in India (typically written as *Arim* or *Arin* in Latin sources).

As for the Indian influences on *Lc*, they are also manifest in the rules for computing eclipse possibilities and the diameters of the Sun, Moon, and Earth's shadow, which are purely arithmetical and do not involve the use of any tables (see pp. 321–324). These rules find close counterparts in a rare set of twelfth-century Latin canons associated with the Toledan Tables as well as in a tenth-century commentary on the original *Sindhind Zīj* by Ibn al-Muthannā, which was translated by Hugo Sanctelliensis (Hugh of Cintheaux?) for Bishop Michael of Tarazona (1119–1151).[28] The fact that Robert inserted them into *Lc* after having previously presented a table of lunisolar velocities derived from al-Battānī evinces a willingness to draw information from disparate sources, without showing much regard for incompatibilities between their respective theories of planetary motion. It may be remarked that this compilatory approach was to an extent a feature of the Andalusian astronomical tradition he inherited, as exemplified by the Toledan Tables.

2 Structure and Style

Lc is an elementary text written for an audience with no prior exposure to computational astronomy in the Hellenistic or Graeco-Arabic tradition. It begins with several chapters discussing the specific calendrical format chosen for the Tables of London as well as the algorithms one could use to convert between dates according to the Julian calendar and Christian era, on the one hand, and dates according to the Islamic lunar calendar and Hijri era, on the other. Robert would have known the latter type of calendrical arrangement from Maslama's recension of al-Khwārizmī's tables, as translated by Adelard of Bath and later revised by his own hand (see p. 199 above), and perhaps also from the Toledan Tables, provided he saw them in their original, non-adapted form.

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[26] See Tab. 115 in Suter 1914: 230, which records an annual rotational excess of 93;2,15°. See also Cc178 in Pedersen (Fritz) 2002: ii. 662. On the sidereal year in the tables of al-Khwārizmī, see Burckhardt 1961: 214–217; Neugebauer 1962: 131–132; van Dalen 2018: 113.

[27] MS Milano, Biblioteca Ambrosiana, H 109 sup., fols. 17^{r} (c. 34).

[28] See Pedersen (Fritz) 1992, and the edition of canons 'Cc' in Pedersen (Fritz) 2002: ii. 571–736. The Latin translation of Ibn al-Muthannā's commentary was edited by Millás Vendrell 1963. On the identity of the translator, see Santoyo 2016.

From the subject of chronology, Robert moves on to explain how the mean-motion tables in the set under discussion, which are intended to be valid for London, can be adapted to other meridians (*Lc*5), and how these tables are correctly entered with a given date before or after the initial epoch of 1 March 1150 (*Lc*6–7). He also includes a chapter explaining how observed times of eclipses can be used to determine the longitude difference between one's own location and the meridian that underlies the London tables. The same chapter concludes with a list of the geographic coordinates of 23 different places, which stands in no obvious relation to any other known list of this kind.

Instead of discussing the rules for computing planetary longitudes in one go, Robert separates the Sun and Moon from the remaining planets. He accordingly moves from discussing the true longitude and declination of the Sun and the true longitude and latitude of the Moon (*Lc*9–13) straight to syzygies and eclipses (*Lc*14–18), in this following an order of exposition familiar from Ptolemy's *Almagest* as well as from al-Battānī's *Ṣābiʾ Zīj*. The section on the five planets covers true longitudes, latitudes, stations/retrogradations, and conjunctions. There is also a chapter explaining how to convert a given time of true syzygy into seasonal hours (*Lc*24). In the two Oxford copies (*A* and *S*), this chapter appears after the discussion of planetary stations/retrogradations, but its original position in the text seems uncertain.

The conversion of equinoctial into seasonal hours, as touched upon in the last-mentioned chapter, is the only instance where the *Lc* ventures, however briefly, into areas of computational astronomy connected with the diurnal motion of the firmament or *primum mobile*. Robert's conversion rule here requires knowledge of the seasonal lengths of day and night, which could be obtained from ascension tables as well as from astrolabes. The overall silence on the astronomy of the *primum mobile* in *Lc* may simply be due to Robert's reluctance to retread ground he had already covered in the first part of the *Liber canonum*, which accompanied tables for the meridian of Toledo. A possible hint in this regard may be discerned in the passage quoted above (p. 194) from his *Liber de officio astrolabii*, which indicates that the complete *Liber canonum* contained a chapter on domification, that is, on the computation of the cusps of the twelve houses.[29] This chapter was presumably contained in the lost first part.

Among the characteristics of Robert's style as an astronomical writer is the avoidance of Arabic loan words or transliterations, which were especially prevalent in early translations such as Adelard of Bath's version of the *zīj* of al-

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[29] For the presence of a chapter on the subject in Robert's revision of the Khwārizmīan *zīj*, see *M*, fol. 49^{vb}, which corresponds to *Ezich Elkaurezmi*, trans. Adelard of Bath, c. 36 (ed. Suter 1914: 29–30).

Khwārizmī. One of the ways in which Robert revised this translation was to swap out Arabic transliterations for Latin words.[30] Significantly, his substitutions tend to converge with the Latin vocabulary in *Lc* and the associated tables, which may be taken as confirmation that the same Robert of Chester was responsible for both *Lc* and the revision of Adelard's translation. It is interesting to note that Robert's technical vocabulary overlaps to a considerable degree with what became the standard terminology in Latin mathematical astronomy until the sixteenth century. This is true, for example, of his use of *equatio* or *coequatio* for 'equation', *centrum* for 'centre', or *argumentum* for 'anomaly'.[31]

An overview of the terms employed in *Lc* and the associated London tables is provided in Table 5, which notes parallel attestations in some other Latin texts of the early-to-mid twelfth century. As these parallels suggest, one should be cautious in treating Robert as an innovator in this area. He very probably inherited *centrum* and *argumentum* from Adelard of Bath, whose translation of al-Khwārizmī he revised. One of the changes Robert made to this translation was to replace Adelard's use of *examinatio* to render *taʿdīl* (تعديل) with *coequatio*, thus literally denoting the act of 'making equal' the mean longitude of a planet with its true position in relation of the firmament. It seems possible that he took this expression from one of the Latin texts produced in association with Abraham Ibn Ezra's Tables of Pisa, which were the source underlying his own mean-motion tables for London. Among these texts were the *Liber de rationibus tabularum* (1154),[32] the *Tractatus magistri Habrahe de tabulis planetarum* (undated, possibly from around 1150),[33] and *Ptolomeus et multi sapientum* (1145).[34] The first two use (*co*)*equatio* as a default term for 'equation'. The third text opts for *directio*, but on a few occasions speaks of the process of achieving an *equatio* between a planet's mean and true position.[35]

Another source worth considering here are the canons to the Toledan Tables starting *Quoniam cuiuscumque actionis quantitatem …*, which are designated 'Cb' in Fritz S. Pedersen's classification.[36] They were the most widely copied set of canons for these tables and played an important role in establishing

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[30] See the tabular comparison in Mercier 1987: 116–118.

[31] For a survey of the technical vocabulary used in medieval Latin astronomical texts, see Poulle 1987.

[32] See the edition in Millás Vallicrosa 1947: 73–167.

[33] This text is still unedited. See *L*, fols. 56^{va}–63^{ra} (s. XII/XIII); Millás Vallicrosa 1947: 59–65; Mercier 1987: 111; 1991: 16–17.

[34] See part I of this volume.

[35] See *Ptolomeus*, III.1, ll. 86–87 (*equatio ad gradum vel minutum firmamenti*), III.2, ll. 154–155 (*circuli minoris et maioris et circuli firmamenti equationem invenire*).

[36] See the introduction, edition, and English translation in Pedersen (Fritz) 2002: ii. 331–499.

TABLE 5 Technical vocabulary in *Lc* with parallel attestations in other sources[a]

	Lc	**Parallels**
anomaly	*argumentum*	AB; Cb; RM (Moon only)
apogee	*absis*	HS
centre	*centrum*	Cb; HS; PA; RM
collected years	*anni collecti*	AB; RM; Ca; Cb; Cc
double elongation	*duplex interstitium*	–
equation	*equatio, coequatio*	Ca; Cb; Cc; JS
expanded years	*anni residui*	–
final equation	*coequatio argumenti coequata*	–
epicyclic increment (of Moon)	*diversitas diametri circuli brevis*	Ca; Cb; RM
greater (additive), lesser (subtractive) distance (of a planet's epicycle)	*altitudo maior, minor*	–
mean longitude	*locus medialis*	–
minutes (of time)	*momenta*	AB
minutes of proportion	*minuta proportionalia*	Cb; RM

[a] The table employs the following sigla: *AB* = Tables of al-Khwārizmī (*Ezic Elkaurezmi*), trans. Adelard of Bath (ed. Suter 1914); *Ca* = canons *Ca* for the Toledan Tables (ed. Pedersen [Fritz] 2002: i. 216–310); *Cb* = canons *Cb* for the Toledan Tables (ed. Pedersen [Fritz] 2002: ii. 382–498); *Cc* = canons *Cc* for the Toledan Tables (ed. Pedersen [Fritz] 2002: ii. 588–720); *HS* = Ibn al-Muthannā, *Commentary on the Tables of al-Khwārizmī*, trans. Hugo Sanctelliensis (ed. Millás Vendrell 1963); *JS* = John of Spain (or Seville), *Sententie de diversis libris excerpte* (ed. Millás Vallicrosa 1936: 459–475); *PA* = Tabes of al-Khwārizmī, trans. Petrus Alfonsi (see Neugebauer 1962: 133–134); *RM* = Raymond of Marseilles, *Liber cursuum planetarum* (ed. Alverny, Burnett, and Poulle 2009: 127–341).

terms such as *equatio centri* and *equatio argumenti* as the standard terms of art in Latin astronomy. Their origins, however, are shrouded in a good degree of uncertainty. According to Pedersen, the text is a Latin adaptation or refashioning of an earlier set of canons (Cc), which was in turn translated from Arabic. If this is the case, and Cb was only produced in the Latin West, the vocabulary in this text, as documented in Table 5, may well have been shaped by Robert's *Liber canonum*. That said, the opposite line of influence cannot be excluded.

3 Transmission

All in all there are five manuscripts that transmit at least some of the chapters originally contained in *Lc*. In the alphabetic order of their sigla, these are:

A	Oxford, Bodleian Library, Ashmole 361, fols. 13^{ra}–28^{r} (England; s. XIV$^{\text{med}}$)[37]
C_2	Cambridge, University Library, Add. 6866, fol. 150^{v} (tables of *Lc*8; XIV$^{\text{in}}$)[38]
L	London, British Library, Arundel 377, fols. 7^{ra}–b, 7^{v}, 10^{v}, 11^{r}, 16^{ra}–17^{rb} (Ely Abbey, Cambridgeshire; s. XII$^{\text{ex}}$)[39]
S	Oxford, Bodleian Library, Savile 21, fols. 86^{r}–95^{v} (England; s. XIII)[40]
S_2	Oxford, Bodleian Library, Savile 25, fol. 203^{r} (partial copy of *Lc*8; England; s. XIV$^{\text{med}}$)[41]

As seen from Table 6, the three principal witnesses—*A*, *L*, and *S*—are all in some degree of disarray when it comes to *Lc*'s chapter sequence. The most coherent and presumably most authentic rendition of the text is that in *S*. For the most part, this manuscript appears to preserve the order originally intended. It deviates noticeably from this hypothetical order, however, by inserting *Lc*12 (on finding the Moon's ascending node) after *Lc*18 (on solar eclipses). There is also some doubt concerning the position of *Lc*24 (on hour-conversions for syzygy times), for which a more natural place would have been after or at least very close to *Lc*14–15 (on true syzygy).

The state of the text in *A* seems especially chaotic as *Lc*1–8 are here placed at the end of the remaining chapters, which are themselves out of sequence. The scribe bookended these remaining chapters with two separate copies of *Lc*13. He also separated *Lc*14 from the velocity table mentioned in it, which appears as the final item after *Lc*8 (fol. 28^{r}). The reason *Lc*13 was copied twice may have been some palpable imperfections in the first copy, which contains misreadings such as *idem* for *quidem*. Other idiosyncrasies in *A*, such as the placement of *Lc*12 ahead of *Lc*11, seem difficult to explain.

Manuscript *L* is the only one to place *Lc*, or parts thereof, next to the corresponding tables for mean motions and equations. It notably omits all the chapters dealing with the computation of mean motions (*Lc*1–8), which the

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[37] For descriptions, see Black 1845: cols. 276–280; Pedersen (Fritz) 2002: i. 138–139; http://www.mirabileweb.it/manuscript/oxford-bodleian-library-ashmole-361-manuscript/116356.

[38] For descriptions, see Ringrose 2009: 283–285; https://www.mirabileweb.it/manuscript/cambridge-university-library-add-6866-manuscript/136655.

[39] Available online: http://www.bl.uk/manuscripts/FullDisplay.aspx?ref=Arundel_MS_377. For descriptions, see British Library online catalogues (Explore Archives and Manuscripts; Catalogue of Illuminated Manuscripts); https://www.mirabileweb.it/manuscript/london-british-library-arundel-377-manuscript/13236; Pedersen (Fritz) 2002: i. 125–126; Miolo 2020: 396–400, 404–406.

[40] For descriptions, see Pedersen (Fritz) 2002: i. 148–149.

[41] For descriptions, see Pedersen (Fritz) 2002: i. 149–150.

TABLE 6 Attestation of chapters of *Lc* in manuscripts *ALS*

	A	*L*	*S*
*Lc*1	19^{vb}–21^{vb}	–	86^{r}–87^{r}
*Lc*2	21^{vb}–23^{rb}	–	87^{r}–87^{v}
*Lc*3	23^{rb}–24^{ra}	–	87^{v}–88^{r}
*Lc*4	24^{ra}–24^{va}	–	88^{r}–88^{v}
*Lc*5	24^{va}–25^{rb}	–	88^{v}–89^{r}
*Lc*6	25^{va}–26^{rb}	–	89^{v}
*Lc*7	26^{rb}–27^{ra}	–	89^{v}–90^{r}
*Lc*8	27^{ra}–27^{vb}	–	90^{r}–91^{r}
*Lc*9	13^{ra}–13^{va}	7^{v}	91^{r}–91^{v}
*Lc*10	19^{va}	–	91^{v}
*Lc*11	17^{ra}–17^{va}	11^{r}	91^{v}
*Lc*12	17^{ra}	10^{r}	93^{v}
*Lc*13	13^{ra}, 19^{va}–19^{vb}	10^{v}	91^{v}–92^{r}
*Lc*14	13^{va}–14^{ra}, 28^{r}	7^{ra}–7^{rb}	92^{r}–92^{v}
*Lc*15	14^{ra}–14^{rb}	16^{va}–16^{vb}	92^{v}–93^{r}
*Lc*16	14^{rb}–15^{ra}	16^{vb}–17^{ra}	93^{r}
*Lc*17	15^{ra}–15^{va}	17^{ra}–17^{rb}	93^{r}–93^{v}
*Lc*18	15^{va}–15^{vb}	17^{rb}	93^{v}
*Lc*19	15^{vb}–16^{rb}	16^{ra}–16^{rb}	93^{v}–94^{r}
*Lc*20	16^{rb}–16^{va}	16^{rb}	94^{r}
*Lc*21	16^{va}–16^{vb}, 17^{ra}	16^{rb}–16^{va}	94^{r}–94^{v}
*Lc*22	16^{vb}–17^{ra}	16^{va}	94^{v}
*Lc*23	17^{va}–18^{vb}	–	94^{v}–95^{r}
*Lc*24	18^{vb}–19^{rb}	–	95^{r}–95^{v}
*Lc*25	$19^{rb\text{–}va}$	–	95^{v}

scribe may have considered self-explanatory.[42] C_2 and S_2 are relatively late additional witnesses to the table for the solar apogee included in *Lc*8. In S_2, the tables are joined by the second half of the corresponding chapter, more specifically ll. 506–520. C_2 is confined to a modified version of the tables themselves, which take up a single page (fol. 150^{v}). That they were excerpted from a copy of *Lc* is confirmed by the heading to this page, which corresponds to that used in *S* and S_2: *Tabula absidis Solis ut per eam absides aliorum planetarum iuxta presens tempus inveniantur* (“Table of the solar apogee, so one can use it to find the apogees of the other planets according to the present time”).

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[42] For reasons that are not fully clear to me, Mercier (1991: 17–18) classified the canons in *L* as a separate text from *Lc*1–8.

Several chapters in *S* feature additions that lack a counterpart in *A* or *L*. They may have originated as marginal glosses to the main text, as is probably also true of certain bits of text attested in the other two manuscripts. For instance, *Lc*23 as transmitted in both *S* and *A* comes with an extension that does not follow seamlessly from the previous parts of the chapter. Most of it deals with the calculation of the time of the vernal equinox, which topic is also dealt with in two other additions unique to *S* (*Lc*9 and *Lc*20). The appendix below presents a selection of the more substantial additions in *A* and *S*, the assumption in each case being that these are not authentic parts of the text as originally conceived by Robert of Chester. Shorter additions of this kind will instead be included in the edition’s critical apparatus.

Manuscript *S* employs Hindu-Arabic numerals (Western forms) almost throughout the text, whereas *A* and *L* restrict their use to the accompanying tables. The preference for Roman numerals in these two witnesses appears to go back to the archetype, whose numerals were later systematically altered by the scribe of *S* or one of his predecessors. Such alterations are still manifest from the way *S* (fol. 87^{v}) represents a number such as ĪĪĪĪCCCLXXXIII in *Lc*2 (l. 162) as ĪĪĪĪ.383 rather than 4383. Similarly, the expression *ducentis XXXIIII secundis* in *Lc*23 (l. 1018) appears in *S* (fol. 94^{v}) as *ducentis 34 secundis*. That Robert himself preferred to write Roman numerals is also suggested by the only extant copy of his revision of the *zīj* of al-Khwārizmī, where they are used consistently even for the tables.[43]

4 The Tables of London

Other than as part of *Lc*8 and *Lc*14 in the witnesses already listed, traces of the astronomical tables for London discussed in *Lc* have survived in the following manuscripts:

D Oxford, Bodleian Library, Digby 114, fols. 25^{r}, 26$^{r–v}$ (England; s. XIV$^{1/2}$): solar and lunar mean motions in collected years, expanded years, and months, mingled with mean-motion tables from the Toledan Tables and Tables of Toulouse.[44]

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[43] See n. 24.

[44] For descriptions of the manuscript, see Pedersen (Fritz) 2002: i. 143–144; David Juste, “MS

L London, British Library, Arundel 377, fols. 7^r–15^v, 17^v–35^r (Ely Abbey, Cambridgeshire; s. xii/xiii): hourly velocities of Sun and Moon; solar apogee; mean motions; equations (see below for details).[45]

P Paris, Bibliothèque nationale de France, lat. 16208, fol. 4^v (France/Italy; s. xii$^{2/2}$): solar apogee, added to mean-motion tables from the Tables of Pisa.[46]

T Toledo, Archivo y Biblioteca Capítulares, 98–22, fols. 104^{vb}–106^{vb}, 107^{va}–112^{rb} (England[?]; s. xiii): solar apogee; planetary mean motions; equations.[47]

The most complete and reliable of these witnesses is *L*, which is also the only one to place the tables next to parts of *Lc* (see § 3). What follows is a concise listing of its tables, with parallel attestations in *DPT* and *Lc* noted in brackets:

- fol. 7^r: hourly velocities of Sun and Moon (see *Lc*14).
- fols. 7^v–8^r: solar mean motion in collected years (*anni collecti*), expanded years (*anni residui*), months, days, hours, and minutes (*D*, fol. 25^r; *T*, fol. 105^{ra}).
- fols. 8^v–9^r: equation tables for the Sun, with columns labelled (i) *linee numeri* and (ii) *equatio Solis* (*T*, fol. 105^{rb}).
- fols. 9^v: precessional motion of the solar apogee in collected years, expanded years, months, and days (*P*, fol. 4^v; *T*, fol. 104^{vb}; see *Lc*8).
- fol. 10^{r-v}: mean motion of the lunar ascending node (*medius cursus capitis Draconis*) in collected years, expanded years, months, days, hours, and minutes (*T*, fol. 106^{vb}).
- fol. 11^{r-v}: lunar mean motion in collected years, expanded years, months, days, hours, and minutes (*D*, fol. 26^r; *T*, fol. 105^{va}).
- fol. 12^{r-v}: lunar mean motion in anomaly (*argumentum Lune*) in collected years, expanded years, months, days, hours, and minutes (*D*, fol. 26^v; *T*, fol. 105^{vb}).

Oxford, Bodleian Library, Digby 114” (update: 04.04.2021), *Ptolemaeus Arabus et Latinus. Manuscripts*, http://ptolemaeus.badw.de/ms/269.

[45] See n. 39.

[46] For descriptions/discussions of this manuscript, see Pedersen (Fritz) 2002: i. 165–166; Miolo 2020: 391–396, 400–406; David Juste, “ms Paris, Bibliothèque nationale de France, lat. 16208” (update: 11.03.2022), *Ptolemaeus Arabus et Latinus. Manuscripts*, url = http://ptolemaeus.badw.de/ms/142.

[47] See Millás Vallicrosa 1942: 202–206; David Juste, “ms Toledo, Archivo y Biblioteca Capitulares, 98–22” (update: 02.03.2022), *Ptolemaeus Arabus et Latinus. Manuscripts*, url = http://ptolemaeus.badw.de/ms/154.

- fols. 13^{r}–15^{v}: equation tables for the Moon, with columns labelled (i) *linee numeri*, (ii) *equatio centri*, (iii) *minuta proportionalia*, (iv) *equatio diversitatis diametri circuli*, (v) *equatio argumenti*, (vi) *latitudo Lune* (*T*, fol. 106^{ra}–106^{va}).
- fol. 17^{v}: mean motion of Saturn in collected years, expanded years, months, days, hours, and minutes (*D*, fol. 27^{r}; *T*, fol. 111^{va}).
- fols. 18^{r}–20^{v}: equation tables for Saturn, with columns labelled (i) *linee numeri*, (ii) *equatio centri*, (iii) *minuta proportionalia*, (iv) *altitudo maior*, (v) *equatio argumenti*, (vi) *altitudo minor*, (vii) *statio prima Saturni* (*accedentis/recedentis*) (*T*, fols. 111^{vb}–112^{rb}).
- fol. 21^{r}: mean motion of Jupiter in collected years, expanded years, months, days, hours, and minutes (*T*, fol. 107^{va}).
- fol. 21^{v}–24^{r}: equation tables for Jupiter, with columns labelled (i) *linee numeri*, (ii) *equatio centri*, (iii) *minuta proportionalia*, (iv) *altitudo maior*, (v) *equatio argumenti*, (vi) *altitudo minor*, (vii) *statio prima Iovis* (*accedentis/recedentis*) (*T*, fols. 107^{vb}–108^{rb}).
- fol. 24^{v}: mean motion of Mars in collected years, expanded years, months, days, hours, and minutes (*T*, fols. 108^{va}).
- fols. 25^{r}–27^{v}: equation tables for Mars, with columns labelled (i) *linee numeri*, (ii) *equatio centri*, (iii) *minuta proportionalia*, (iv) *altitudo maior*, (v) *equatio argumenti*, (vi) *altitudo minor*, (vii) *statio prima Martis* (*accedentis*) (*T*, fols. 108^{vb}–109^{rb}).
- fol. 28^{r}: mean motion in anomaly of Venus in collected years, expanded years, months, days, hours, and minutes (*T*, fol. 110^{va}).
- fols. 28^{v}–31^{r}: equation tables for Venus, with columns labelled (i) *linee numeri*, (ii) *equatio centri*, (iii) *minuta proportionalia*, (iv) *altitudo maior*, (v) *equatio argumenti*, (vi) *altitudo minor*, (vii) *statio prima Veneris* (*T*, fols. 110^{vb}–111^{ra}).
- fols. 31^{v}–32^{r}: mean motion in anomaly of Mercury in collected years, expanded years, months, days, hours, and minutes (*T*, fols. 109^{va})
- fols. 32^{v}–35^{r}: equation tables for Mercury, with columns labelled (i) *linee numeri*, (ii) *equatio centri*, (iii) *minuta proportionalia*, (iv) *altitudo maior*, (v) *equatio argumenti*, (vi) *altitudo minor*, (vii) *statio prima Mercurii* (*T*, fols. 109^{va}–110^{rb}).

In terms of their numerical content, their overall structure, and the vocabulary used in their headings, the tables copied into *L* fully match the specifications mentioned in *Lc*, leaving no reasonable doubt that they stem from the set that originally accompanied Robert's work. The only components mentioned in *Lc* that have no counterpart in *L* are the table for the solar declination (*Lc*10) and the Khwārizmīan table for planetary latitudes (*Lc*21).

The mean-motion tables all display mean longitudes according to signs, degrees, minutes, and seconds of arc. Their calendrical format is Julian, with a beginning of the year on 1 March. The first line of each collected-year table is labelled *radix*, the second *29*, after which the arguments increase in steps of 20 years, for a total of 29 lines (to 569). A note on fol. 7^{r} points out that 1141 years must be added to the years in the collected-year table to obtain the relevant year AD. This all fully agrees with the way the collected-year tables are described in *Lc*1, *Lc*4, and *Lc*6–7. The number of lines in the remaining subtables are as follows:

- Expanded years: 20 (steps of 1y)
- Months: 12 (March to February)
- Days: 30 (steps of 1d)
- Hours: 24 (steps of 1h)
- Minutes: 30 (steps of 2m)

Raymond Mercier, in a paper first published in 1991, demonstrated that the mean-motion tables in *L* are classifiable as a variant of the Tables of Pisa, the set Abraham Ibn Ezra constructed in 1143 on the basis of an earlier *zīj* by the Persian astronomer al-Ṣūfī (d. 986).[48] As with Robert's Tables of London, Ibn Ezra arranged his tables for expanded and collected years according to a 20-year increment. Their original *radix* corresponded to 1029 collected years, or 1 March 1030, which is exactly 6 × 20 = 120 years ahead of the *radix* assumed in the London tables. The process of adapting the Tables of Pisa for London hence presumably involved removing all lines from the collected-year tables that were applicable only to dates in the past, beginning instead with 1149 collected years. Whoever created the London adaptation also extended the original collected-year tables far into the future, by computing entries up to 569 collected years = 1 March 1710.

Table 7 compares the rates of mean motion implicit in the tables for expanded years in *L* with those in the Tables of Pisa.[49] In each case, the mean-motion increment for 20 years—expressed as the number of completed revolutions (r = 360°) + the difference at the end of 20 years—has been divided by 365.25d × 20 = 7305d to yield the daily rate (here displayed to the fifth sexagesimal-fractional place, not rounded). As seen, the two sets of tables converge in all

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[48] Mercier 1991. See the additional discussions of the London tables in Mercier 1987: 108–109; Pedersen (Fritz) 2002: iii. 1209 (CE25); North 2002: 15–19; Chabás 2019: 118–120 (where the mean-motion *radix* is erroneously identified as AD 1009). For details concerning the Tables of Pisa, see § 2 in part I of this volume.

[49] For the Pisan values, see Mercier 1991: 24; Pedersen 2007: 7–12; Samsó 2020: 825. I have also checked the copies in *P*, fol. 4^{r-v}, and *V*, fols. 1^{v}–42^{r}.

TABLE 7 Rates of mean motion in the Tables of Pisa and London

	Motion per 20 years		Implied daily rates	
	Pisa	**London**	**Pisa**	**London**
Sun	20^{r} + 0;9°	same	0;59,8,19,42,45°	same
Moon	267^{r} + 133;43,34°[a]	same	13;10,35,6,4,11°	same
Lunar anomaly	265^{r} + 39;46,50°	265^{r} + 39;41,30°	13;3,53,58,41,8°	13;3,53,56,3,26°
Lunar node	1^{r} + 26;47,17°	same	0;3,10,36,51,15°	same °
Saturn	0^{r} + 244;40°	same	0;2,0,34,29,48°	same
Jupiter	1^{r} + 247;16,25°	1^{r} + 247;16°	0;4,59,16,20,41°	0;4,59,16,8,22°
Mars	10^{r} + 228;19,10°	same	0;31,26,38,46,4°	same
Venus (anom.)	12^{r} + 183;43,18°	same	0;36,59,29,35,36°	same
Mercury (anom.)	63^{r} + 14;28,50°	same	3;6,24,8,17,44°	same

a Mercier (1991: 4, 24) suggests an emendation towards 133;33,34°. Since most witnesses to the Pisan tables agree with the London tables on making the collected-year radices rise by 133;43,34°, I have accepted this—undoubtedly corrupt—value for both sets. See also Pedersen 2007: 8.

but two cases. For the Moon's mean motion in anomaly, the extant copies of the Pisan tables show an unrealistically low 20-year increment of 39;46,50°. The value used in the Tables of London (39;41,30°) is much closer to that in al-Battānī's mean-motion tables (39;41,59°).[50] The discrepancy between the two sets is more moderate in the case of Jupiter. In the Tables of Pisa, the collected-year and expanded-year tables both agree on a 20-year increase of 247;16,25°, whereas the Tables of London operate with an increase of 247;16,0°. Also worth noting is a disagreement within the Tables of Pisa with respect to the mean motion of Saturn. The collected-year table here operates with a 20-year increment of 244,40,2°, whereas the expanded year-table ends on a round 244,40,0°, as shown in Table 7. The collected-year table for Saturn in the Tables of London supports the latter value.

The available sources on the Tables of Pisa, in particular Abraham Ibn Ezra's *Liber de rationibus tabularum* and the *Tractatus magistri Habrahe de tabulis planetarum*, agree on placing Pisa 33° from the western prime meridian.[51] This happens to match the longitude of Pisa recorded in the list of geographic coordinates Robert added to *Lc*5. The same list assigns a longitude of 18° to 'England' (*Anglia*). By contrast, a heading placed above the solar mean-motion tables in *L* (fol. 7^{r}) expressly states that the longitude of London is 19° (*medius cursus Solis ad annos domini collectos super Londonias, quarum longitudo est* XIX *graduum*). The same longitude of 19° is assigned to Winchester in an astronomical calculation that accompanies a partial Latin translation of an astrological text by Abraham Ibn Ezra (*ʿOlam* III, § 7.1:4, p. 252). The author of this calculation, who one may suspect to have been Ibn Ezra himself, used mean-motion tables for Winchester that were evidently another adaptation of the Tables of Pisa.[52]

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[50] For al-Battānī's value, see Nallino 1899–1907: ii. 77. Mercier (1991: 24) wrongly gives the Pisan value as 39;46,30° and suggests replacing it with the London one.

[51] See Abraham Ibn Ezra, *Liber de rationibus tabularum* (ed. Millás Vallicrosa 1947: 87, ll. 20–21); *Tractatus magistri Habrahe de tabulis planetarum* (*L*, fol. 56va).

If the creator of the Tables of London accepted 19° as the longitude of London and 33° as the longitude of Pisa, one would expect him to have increased the mean-motion radices in the Tables of Pisa by the equivalent of 0;56h to effect an adjustment to the meridian of London (33° − 19° = 14°, while 14°/360° = 0;56h/24h). To test this hypothesis, I have subtracted from the initial radices in the Tables of London the mean motion in 0;56h, as shown in *L*'s tables for minutes. Table 8 compares the results of this subtraction with the radices for 1149 years according to the Tables of Pisa.[53] In the cases of the Moon (mean motion), the lunar ascending node, and the anomalies of Venus and Mercury, the stated procedure leads to a perfect match between the two sets. The same is true of Saturn if the *radix* in the Tables of Pisa is emended by a simple conjecture. As has been mentioned above, the extant copies of the Tables of Pisa increase Saturn's collected-year radices by 244,40,2°, whereas the London tables use the 20-year value shown in the expanded-year table, which is 244,40,0°. If this increment is applied to the initial *radix* of the Pisan tables, the result for 1149 years will be 91;30°, exactly as predicted by the subtraction of 0;56h from the London *radix*.[54]

The lack of agreement between the radices for the lunar anomaly and Jupiter was to be expected, seeing as these are the two mean motions for which the Tables of Pisa and London employ different rates. Putting these to one side leaves us with Mars, the Sun, and the lunar ascending node, where the subtraction of 0;56h reveals discrepancies of 0;0,1° (Mars), 0;1° (Sun), and 1° (node).

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[52] See my discussion in Sela, Steel, Nothaft, Juste, and Burnett 2020: 209–222.

[53] I have inferred these from the radices for 1169 years shown in Pedersen 2007: 7–11. Most copies of the Tables of Pisa only set in at 1169 years, even though the original radix was 1029 years. This original beginning is still reflected in *V*, fols. 1^{v}–42^{r}. See § 2 in part I.

[54] The initial radix (1029 years) for Saturn was 83;30° according to *V*, fol. 21^{v}. Assuming a 20-year increment of 244;40°, the expected value for 1149 years is 91;30°.

TABLE 8 Comparison of radices for 1 March 1150 in the Tables of Pisa and London

	London	**−0;56h**	**Pisa**	**Δ**
Sun	345;25,38°	345;23,20°	345;24,20°	−0;1°
Moon	357;7,4°	356;36,19°	356;36,19°	–
Lunar anomaly	113;9,30°	112;39,1°	112;44,1°	−0;5°
Lunar node	357;53,23°	357;53,15°	358;53,15°	−1°
Saturn	91;30,5°	91;30,0°	91;30,0°	–
Jupiter	153;4,21°	153;4,10°	153;2,32°	+0;1,38°
Mars	49;4[2],12°[a]	49;41,0°	49;41,1°	−0;0,1°
Venus	5[9];31,51°[b]	59;30,25°	59;30,25°	–
Mercury	107;56,13°	107;49,0°	107;49,0°	–

[a] *L*, *T*, and Mercier (1991: 23) show 49;49,12°. If this value is emended to 49;42,12°, it becomes consistent with the following lines in the collected-year tables.

[b] *L*, *T*, and Mercier (1991: 23) show 52;31,51°. Again, the emendation was required to make the initial radix consistent with the following ones.

These could be explained as the result of scribal errors or erroneous readings of the entry for 0;56h in the mean-motion tables. In the specific case of the Sun, a value of 0;2,18° may have been mistaken for 0;1,18°.[55]

Overall, the results of this comparison would seem to confirm that Robert of Chester's mean-motion tables were indeed derived from the Tables of Pisa on the assumption of a time-difference of 0;56h, although some discrepancies remain.[56] It remains an open question whether Robert carried out this adaptation himself or whether he used a pre-existing set, perhaps mistaking it for an adaptation of al-Battānī's mean-motion tables (see pp. 197–198). The latter scenario receives some support from a text written in 1181 to explain the Tables of London, which begins *Motuum Solis alius est medius …* (see § 6). Here the claim is made that the meridian of reference for the mean-motion tables in question was adjusted from Toledo(!) to London by one *Alabertus Unebaldus* (*T*, fol. 1^{rb}).

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[55] In that case, the longitude difference of 8° inferred by North (2002: 18) and confirmed by Nothaft (in Steel, Sela, Nothaft, Juste, and Burnett 2020: 213) would turn out to be a red herring.

[56] This conclusion is in harmony with that reached by Mercier (1991: 4). His method of demonstration (see Mercier 1991: 24–25) differs from the one attempted here. For another discussion of this question, see North 2002: 18–20, who assumed that Abraham Ibn Ezra was responsible for both sets of tables.

The incorrect suggestion that the Tables of London were derived from the Toledan Tables becomes somewhat less surprising if one bears in mind that the influence of Ibn Ezra's Tables of Pisa on *Lc* was limited to the mean-motion tables. Copying errors aside, the equation tables in *L* and *T* are structurally and numerically identical with those that were disseminated as part of the Toledan Tables. These 'Toledan' equation tables were in turn an adaptation of the equation tables in al-Battānī's *Ṣābi' Zīj*, which were modified by adding a column for the first station (*statio prima*).[57] A parallel origin is in evidence for the table of hourly velocities included in *Lc*14, which is again attested among the Toledan Tables and ultimately rooted in the *Ṣābi' Zīj*.[58]

The tables for the solar apogee incorporated into *Lc*8 assume that the apogees and fixed stars all move at a uniform rate of 0;0,54°/d, which can be interpreted as a rounded version of al-Battānī's precession value of 1°/66y = 0;0,54,32,43...°/y (see pp. 314–315). Some further evidence that Robert worked with data derived from al-Battānī is hidden in the values the Tables of London in *L* record for the apogees of the Sun and five planets at *radix* = 1 March AD 1150.[59] Table 9 lists all six of these values and places them next to the apogeal longitudes mentioned in the *Ṣābi' Zīj*. According to al-Battānī, these longitudes were valid for year 1191 of the Seleucid era, which on his count ran from 1 March AD 879 to 29 February 880. He is more precise only in the case of the solar apogee, citing an epoch of 1 Adhar 1191 = 1 March AD 879.[60]

As seen from Table 9, all six apogeal longitudes recorded in the Tables of London end on 18 seconds of arc, which is a sign that they were derived by adding an identical precessional increment to an earlier set of values that was precise only to minutes of arc. That this earlier set of values may have come from al-Battānī is suggested by the entries in the rightmost column, which are the result of subtracting 4;5,18° from those in the first column. They are identical with the apogeal longitude known from al-Battānī only in the case of Mercury. Nevertheless, all other entries have a plausible origin as possible scribal variants of al-Battānī's values, with discrepancies of +1° (Saturn), −2° (Jupiter), +1;10° (Mars), and +0;1° (Venus and the Sun). In the case of the solar

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[57] Pedersen (Fritz) 2002: iv. 1245–1307 (EA). See also Toomer 1968: 56–68; Samsó 2020: 734. For al-Battānī's original equation tables, see Nallino 1899–1907: ii. 78–83, 108–137.

[58] Pedersen (Fritz) 2002: iv. 1409–1412 (JA11). See also Toomer 1968: 82–84; Chabás and Goldstein 2012: 95–96. For al-Battānī's original, see Nallino 1899–1907: ii. 88.

[59] See the notes accompanying the table for the solar apogee and the mean-motion tables for the five planets in *L*, fols. 9^v, 17^v, 21^r, 24^v, 28^r, 31^v.

[60] See al-Battānī, *Opus astronomicum*, c. 33, 45 (ed. Nallino 1899–1907: i. 72, 114). There are slight variations between these values and those listed in the headings of the planetary equation tables (ed. Nallino 1899–1907: ii. 108, 114, 120, 126, 132).

TABLE 9 Comparison of apogeal longitudes in the Tables of London with those in al-Battānī's *Ṣābiʾ Zīj*

	Tables of London	**−4;5,18°**	**al-Battānī**	**Δ**
Sun	86;21,18°	82;16°	82;15°	+0;1°
Saturn	249;33,18°	245;28°	244;28°	+1°
Jupiter	166;33,18°[a]	162;28°	164;28°	−2°
Mars	131;33,18°	127;28°	126;18°	+1;10°
Venus	86;20,18°[b]	82;15°	82;14°	+0;1°
Mercury	205;33,18°	201;28°	201;28°	–

[a] *L* appears to have 176;33,18°.
[b] *L* has 86;2,18°.

apogee, the starting position given in *L* (fol. 9^{v}) and most copies of the table in *Lc*8 is 86;20,18°, which is precisely 4;5,18° higher than al-Battānī's value. As the relevant entry in the first column of Table 9, I have nevertheless selected the variant 86;21,18°, which is attested in C_2 and in a gloss preserved in *S* (fol. 38^{r}).[61] Its greater authenticity is suggested by the following entries in the collected-year table of *Lc*8 (see below, pp. 258, 316), which are inconsistent with an initial entry of 86;20,18°. Moreover, by raising the epoch value of the solar apogee to 86;21,18° one is able to preserve the peculiar difference of 0;1° between the Sun and Venus that characterizes al-Battānī's apogeal longitudes. Indeed, the variant of 86;20,18° for the Sun may have been introduced to ensure a perfect match with Venus's apogee.

The epoch dates used by Robert (1 March 1150) and al-Battānī (1 March 879) for their respective sets of apogeal longitudes are separated by precisely 271 years. According to the precession table included in al-Battānī's *zīj*, the precessional increment over this period should have been 3;56,22° + 0;10° = 4;6,22°.[62] An increase of merely 4;5,18° is instead suggestive of an interval of 269 years and 10 months, which according to al-Battānī's precession table would amount to 3;56,22° + 0;8,11° + 0;0,46° = 4;5,19°. One may note in passing that adding this interval of 269 years and 10 months to al-Battānī's epoch of 1 March 879 would yield a result very close to the epoch of the Toledo tables in the lost first part of the *Liber canonum*, which was 1 January 1149. Another possibility one ought to consider is that al-Battānī's year 1191 of the Seleucid era was misinterpreted as referring to AD 880, in which case an increase of 4;5,18° would point to a date closer to the beginning of Robert's London tables.

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[61] See n. 46 on p. 316.

[62] Nallino 1899–1907: ii. 107.

The hypothesis that the apogees in these London tables were derived from al-Battānī by adding 4;5,18° was already considered by Mercier, who ended up rejecting it, arguing instead that the source used was the lost *zīj* of al-Ṣūfī.[63] Yet the London tables' dependency on al-Ṣūfī is merely indirect, seeing as they are an adaptation of the Tables of Pisa. Since these tables employed neither the same epoch values for the planetary apogees nor the same rate of precession (0;0,51°/y rather than 0;0,54°/y),[64] al-Battānī remains a far more plausible guess.

5 The Tables of Toledo

Near the beginning of *Lc*1 (ll. 13–14), Robert refers back to the first part of his *Liber canonum*, which contained mean-motion tables for the meridian of Toledo and was founded on the authority of an individual whose name appears as *Ebeneza et Toletanum* in *A* and as *Ebenza et Toletanum* in *S*. Both forms of the name are obviously corrupt and call for some sort of emendation. Lutz Richter-Bernburg has made the plausible conjecture that the text originally read *Ebenzaet Toletanum* and that the *-et* suffix was turned into the abbreviation for *et* ("and") through a scribal mistake.[65] If this is the case, *Ebenzaet* is very likely to be a transliteration of the name of Ṣāʿid al-Andalusī, the well-known *qāḍī* of Toledo (1029–1070) who reportedly led the group of astronomers who created the famous Toledan Tables.[66] Robert's *Liber canonum* is one of the earliest known texts to attest to the dissemination of these tables in the Latin West, where they became the dominant set during the latter half of the twelfth as well as the thirteenth and early fourteenth centuries.[67]

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[63] Mercier 1991: 11–12, 26.

[64] See pp. 141–142, 180–181.

[65] See Richter-Bernburg 1987: 375, 392 (n. 9c), who is followed by Pedersen (Fritz) 2002: iii. 756. That said, Richter-Bernburg was mistaken in identifying the first part of Robert's text with "the Toledan *Canones* in Gerard of Cremona's version" (Richter-Bernburg 1987: 375), which are canons *Cb* (ed. Pedersen [Fritz] 2002: ii. 382–498). Mercier (1987: 109n63; 1991: 18) thought the name refers to Ibn Ezra, which seems implausible for historical reasons.

[66] On Ṣāʿid, see Richter-Bernburg 1987; Samsó 2020: 163–164, 579–580, 721–722.

[67] The Latin versions of the Toledan Tables and their canons were edited and analysed in four volumes by Pedersen (Fritz) 2002. See also Toomer 1968; King and Samsó 2001: 58–59; Chabás 2019: 47–75; Samsó 2020: 719–734.

The Toledan Tables presented in the first part of the *Liber canonum* differed from their common version at least in the sense that their mean-motion tables had been converted from the Islamic calendar and Hijri era to a Christian calendrical format. Specifically, Robert's version operated with Julian years that began on 1 January and were counted according to the Christian *Anno Domini* era (*Lc*1, ll. 16–17). The tables of collected years were computed for intervals of 28 years, which by implication was also the number of years displayed in the tables of expanded years (*Lc*4, ll. 272–275). This 28-year period was intentionally chosen for being equivalent to the so-called 'solar cycle', which governed the relationship between dates in the Julian calendar and days of the week. As a consequence, each date listed in the collected-year table coincided with the same day of the week. The initial *radix* of the whole table was 1 January AD 1149 (*Lc*4, l. 273, which is exactly 41 × 28 = 1148 years removed from the beginning of the Christian era on 1 January AD 1.[68]

This calendrical format is familiar from the earliest known Christian adaptation of the Toledan Tables, the Tables of Marseilles, which were originally part of Raymond of Marseilles's *Liber cursuum planetarum* (1141).[69] In Raymond's version, the radices of the collected-year tables were once again spaced by 28-year intervals, extending from AD 1 in the first to AD 1905 in the final line. The values of these radices were adapted to the meridian of Marseilles on the assumption that this city lies 16;30° = 1;6h east of Toledo. In the accompanying text, Raymond signals his familiarity with the original format of the Toledan Tables, which was based on the Islamic calendar, and takes credit for changing the calendrical format to one founded on the Julian year and Christian era.[70] The collected-year tables in Raymond's work consistently begin from 1 January AD 1. Removing the first 41 lines from these tables will accordingly shift the initial date to 1 January 1149, which is the date Robert declares to be the *radix* of the Toledan Tables discussed in the first part of the *Liber canonum*.

There are other reasons for suspecting that Raymond's and Robert's versions of the Toledan Tables may be closely related. One of these is hidden in Robert's comments in *Lc*1 on the position of the bissextile day in the Toledan

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[68] Mercier (1991: 18) followed *A* in reading 1 January 1169. Yet *S*'s reading of 1149 is supported by the comparison with the Tables of Marseilles, to be made in what follows.

[69] Edited with a French translation in Alverny, Burnett, and Poulle 2009: 126–341. On the Tables of Marseilles, see also Pedersen (Fritz) 2002: iii. 754–755, 760–761, 1210 (CE33); Chabás 2019: 104–106, 113.

[70] Raymond of Marseilles, *Liber cursuum planetarum* 1.10, 2.1 (ed. Alverny, Burnett, and Poulle 2009: 140, 200).

Tables. According to him, one of the drawbacks of beginning the year on 1 January for computational purposes was that the position of the bissextile day in the second month of the year was bound to cause a disturbance of the "natural sequence" (*naturalis series*) of expanded years (*Lc*1, ll. 13–21). His remarks resonate with a set of auxiliary tables included in Raymond's Tables of Marseilles, which show the mean-motion increment of the planets (and the lunar node) at the start of years 3, 7, 11, 15, 19, 23, and 27 of a 28-year period of collected years (heading: *ad annos* VII *bissextilis temporis absque bissexto superstites*). Their purpose was to facilitate the use of the mean-motion tables for Marseilles in these seven bissextile years, in which the entries listed in the ordinary expanded-year table were not applicable to January and the part of February prior to the bissextile day (i.e., the day inserted by doubling the sixth before the Kalends of February, or 24 February).[71]

Apart from this characteristic feature, Raymond's tables are also notable for the absence of several components that one may consider integral to a fully-fledged *zīj* such as were the Toledan Tables. Specifically, the Tables of Marseilles included tables for planetary equations, planetary stations, lunar latitude, planetary latitudes, the solar declination, and the hourly velocity of Sun and Moon, but lacked tables for syzygies, eclipses, and parallax as well as right and oblique ascensions. It may not be a coincidence that these are the same types of tables that are conspicuous by their respective presence and absence from the Tables of London in *Lc*. In fact, another striking lacuna in the Tables of Marseilles concerns the Toledan tables for the 'access and recess' of the eighth sphere, whose absence confined users of Raymond's tables to working with sidereal longitudes. This omission coincides with a failure on Robert of Chester's part to include the 'access-and-recess' theory in his account of precession in *Lc*8. In fact, the preserved parts of the *Liber canonum* are completely silent on the existence of two difference reference frames for computing planetary longitudes, sidereal and tropical. It seems possible, in fact, that Robert was simply unaware of this important distinction, as was also clearly the case with Raymond of Marseilles.[72]

It seems significant, moreover, that the earliest surviving witnesses to Raymond's Tables of Marseille follow an Iberian custom of abbreviating the system of Roman numerals with the help of alternative shapes such as *O* for 8, hence writing *XXO* instead of *XXVIII*.[73] We find the same usage of *O* in manuscript *A*'s rendition of *Lc*, which may be a hint that Raymond and Robert drew on a shared Latin source. *A*'s copy of the precession table of *Lc*8 (*A*, fol. 27^{v}), besides featuring the same *O*-shape, also employs the symbol *t* to represent '30', as in 't6' for '36'. This is again a prominent feature of one of the extant copies of the Tables of Marseille, contained in *C* (fols. 51^{r}–66^{v}), which dates from the last quarter or third of the twelfth century.

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[71] Raymond of Marseilles, *Liber cursuum planetarum* 1.96, 2.27, Tab. 24 (ed. Alverny, Burnett, and Poulle 2009: 194, 230–232, 341).

[72] On Raymond's lack of awareness in this area, see Nothaft 2021b: 49–54.

A final point worth mentioning may be that *A*'s use of *O* as a symbol for the number 8 extends to an obscure work on astronomy beginning *Infra signiferi poli regionem …*, which appears in the same manuscript immediately after *Lc* (fols. 28^{va}–34^{va}). This treatise shares most of its second half in common with another anonymous text, *Circulorum alius est sub quo …*, which is found in MS Firenze, Biblioteca Nazionale Centrale, Conv. soppr. J.II.10, fols. 227^{ra}–231^{va} (s. XIII/XIV). Despite their surface-level differences, moreover, the parts where the two texts diverge are close enough doctrinally to support the view that *Infra signiferi poli regionem* and *Circulorum alius est sub quo* originated as alternative recensions of the same work. The evident purpose of this work was to elucidate a specific set of astronomical tables by offering computational rules and an account of the underlying theories of planetary motion, which in some areas deviates significantly from Ptolemaic conventions. Throughout both recensions, the vocabulary employed, the numerical values cited, and various other specifics mentioned agree to a striking degree with the Tables of Marseilles, leaving little doubt that these are the tables under discussion. It seems likely, therefore, that the work represented by *Infra signiferi poli regionem* and *Circulorum alius est* originated as a twelfth-century effort to elucidate the Tables of Marseilles to a greater extent than had been done in Raymond of Marseilles's own *Liber cursuum planetarum*, which had very little to say about the kinematic models behind his equation tables.[74]

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[73] MSS Angers, Bibliothèque municipale, 280, fols. Ar–Hr (s. XII); *C*, fols. 51^{r}–66^{v}; Paris, Bibliothèque nationale de France, lat. 14704, fols. 120^{r}–135^{v} (s. XII). On this and other modifications of the Roman numeral system, see Lemay 1977: 457–459; Burnett 2020: 28. Other astronomical manuscripts featuring the *O*-symbol for the letter *VIII* include the Khwārizmīan tables (Toledan adaptation) in MS Darmstadt, Universitäts- und Landesbibliothek, 765, fols. 204^{r}–214^{v} (s. $\mathrm{XIII}^{1/2}$), and the perpetual almanac in MS London, British Library, Royal 7.F.VIII, fols. 180^{r}–191^{v} (s. $\mathrm{XIII}^{2/2}$).

[74] A separate study of these two recensions and their approach to planetary theory is in preparation.

6 Reception

The Tables of London are the subject of at least three other medieval Latin texts written subsequent to *Lc*. All three are transmitted anonymously in their respective manuscripts and none appears next to the tables for which it was written. One major feature that sets these texts apart from *Lc* is that they deal at length with the (mostly Ptolemaic) theories of planetary motion that underlie the computational tables at hand. Another is that they include extensive accounts of the theory and calculation of eclipses, which is a topic *Lc* covers only briefly and incompletely. It seems reasonable to assume that all three of these texts originated in England, as is probably true of *Lc*, yet neither their place of origin nor their date can be established with any precision. Their incipits are as follows:

- *Investigantibus astronomiam primo sciendum* … Edited by Fritz Pedersen (1990) from two full copies plus several fragments.
- *Motuum Solis alius est medius* … in *T*, fol. 1^{ra-vb} / *Nostri temporis astronomici* … in MS Leipzig, Universitätsbibliothek, 1487, fols. 53^{r}–67^{r}.
- *Circulus Solis dicitur esse ecentricus* … MSS Cambridge, University Library, Kk.1.1, fols. 192^{r}–203^{r} (s. XIII$^{2/4}$); Oxford, Bodleian Library, Digby 193, fols. 1^{ra}–9^{rb} (acephalous fragment; s. XIV).

The only one of these works to have been printed thus far is *Investigantibus astronomiam primo sciendum*, which Pedersen, its editor, dates to the fourth quarter of the twelfth century.[75] It is the one text among the three to show the strongest degree of dependency on the chapters and terminology in *Lc*.[76] Specifically, the author borrowed material from *Lc*9,[77] *Lc*11,[78] *Lc*13,[79] *Lc*21,[80] as well as parts of *Lc*8,[81] *Lc*14–15,[82] *Lc*16,[83] *Lc*17–18,[84] *Lc*19–20.[85] He worked with equation tables for the five planets whose headings were the same as those in the Tables of London preserved in *L* and *T* (see § 4).[86] Likewise, his account of how to construct tables for the Sun's mean motion agrees exactly with the structural principles and parameters familiar from the Tables of London.[87] A critical attitude towards his source is revealed by his complaint that "most people" (*plerique*) provide an incomplete account of computing the lunar latitude, because they ignore cases where the equation table must be entered with an argument of latitude that includes minutes of arc or other small fractions of a degree.[88] Robert had glossed over this scenario in *Lc*13 since he had already given the appropriate instructions in *Lc*9 (for the solar equation) and presumably expected his readers to know how to apply their analogue in all subsequent operations.

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[75] Pedersen (Fritz) 1990: 199.

[76] See the discussion in Pedersen (Fritz) 1990: 211–214, 216–218.

[77] Jn50–56 (ed. Pedersen [Fritz] 1990: 233–234).

[78] Jn76–77, 412–413 (ed. Pedersen [Fritz] 1990: 237).

[79] Jn79 (ed. Pedersen [Fritz] 1990: 238).

[80] Jn423–424 (ed. Pedersen [Fritz] 1990: 308).

[81] Jn218–219, 227 (ed. Pedersen [Fritz] 1990: 266–268, 305).

[82] Jn255–258 (ed. Pedersen [Fritz] 1990: 272–273).

[83] Jn250, 403 (ed. Pedersen [Fritz] 1990: 272, 304).

[84] Jn251, 288–289 (ed. Pedersen [Fritz] 1990: 272, 281).

[85] Jn131–133, 139 (ed. Pedersen [Fritz] 1990: 248–249).

[86] Jn137 (ed. Pedersen [Fritz] 1990: 249).

Investigantibus astronomiam appears to have been one of the sources used in compiling, at some point before the mid-thirteenth century, the vastly popular *Theoricae planetarum* sometimes attributed to Gerard of Cremona.[89] One instance where this use of *Investigantibus* led to an indirect influence of *Lc* on the *Theorica* can be discerned in a passage that mentions al-Battānī as having made the apogees move at a rate of 1° in 60 years and 4 months, which corrupts *Lc*8's value of 1° in 66 years and 8 months.[90] Another is the appearance of the *duplex interstitium* as one possible expression for the Moon's double elongation. This term probably entered the *Theorica* through *Investigantibus astronomiam*, which in turn received this and other technical terms from *Lc*.[91]

The first leaf of a text beginning *Motuum Solis alius est medius*, written in 1181, has been preserved in *T*, a thirteenth-century manuscript (fol. 1^{ra-vb}). It once belonged to a fuller and presumably earlier recension of the text starting *Nostri temporis astronomici*, which is known solely from the fourteenth-century MS Leipzig, Universitätsbibliothek, 1487, fols. 53^r–67^r.[92] The text underlying these two recensions repeatedly discusses mean-motion tables for the meridian of London, the specifics of which correspond to those in *L* and *T*.[93] According to *Motus Solis*, the tables in question were an adaptation of an earlier set for Toledo, allegedly carried out in 1149 (*T*, fol. 1^{rb}). The name of the person responsible for this adaptation is supplied, but no longer clearly legible in the manuscript. It appears to be *Alabertus Unebaldus* (ibid.).

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[87] Jn354–367 (ed. Pedersen [Fritz] 1990: 296–299).

[88] Jn79–80 (ed. Pedersen [Fritz] 1990: 238).

[89] Pedersen (Fritz) 1990: 221–222.

[90] *Theorica planetarum Gerardi*, § 110 (ed. Carmody 1942: 46). Cf. Jn219, 227 (ed. Pedersen [Fritz] 1990: 266–268, 305).

[91] *Theorica planetarum Gerardi*, § 11 (ed. Carmody 1942: 19).

[92] See the brief notes on this manuscript/text in Zinner 1962: 39; Pedersen (Fritz) 1990: 212, 215; 2002: i. 124; ii. 530. See also the commentary on *Ptolomeus*, III.ii, in part I of this volume.

[93] MS Leipzig, Universitätsbibliothek, 1487, fols. 53^v–55^r, 66^v–67^r.

Lc and the Tables of London have left a noticeable mark on the way *Nostri temporis astronomici* describes the motions and equations of the five planets. For instance, the two halves of the epicyclic increment are here referred to as *altitudo maior* and *minor*, as in *Lc*, rather than the more common *longitudo longior* and *propior*.[94] That said, a rather large portion of this text is concerned with topics not immediately related to the Tables of London, such as eclipses, parallax, and the equation of time. For these, the author instead drew on the Toledan Tables.[95]

A technical vocabulary that is for the most part consistent with *Lc* also characterizes *Circulus Solis dicitur esse eccentricus*, which was probably the latest of the three texts discussed in this section.[96] The only complete copy known to date occupies a single quire in MS Cambridge, University Library, Kk.1.1, fols. 192^{r}–203^{r}, and may have been written in the second quarter of the thirteenth century.[97] Among the numerous other items in the same codex is a copy of the Toledan Tables (fols. 144^{v}–172^{v}), which was annotated by someone familiar with the Tables of London. They are mentioned repeatedly on a page containing the mean-motion tables for the Moon (fol. 147^{r}), which features marginal glosses commenting on the specific points where the numbers in the London tables for the mean Moon and its anomaly diverge from those in their Toledan counterpart.[98]

Unlike *Investigantibus* and *Nostri temporis astronomici*, which cover all planetary motions, the text beginning *Circulus Solis dicitur esse eccentricus* limits its attention to the Sun and Moon.[99] Whoever wrote it must have seen a copy of the Tables of London similar to *L*. At the same time, the text offers extensive explanations of tables that seem extraneous to the Tables of London, in particular on the subject of parallax and the magnitudes and durations of eclipses.[100] The author repeatedly speaks of the maker of the Tables of London in the third person, but without mentioning Robert of Chester's name. What he does preserve is the information, also highlighted in *Lc*, that the tables were somehow based on al-Bāttanī (*Albategnius tamen, secundum quem facte sunt iste tabule*). According to the same passage, al-Bāttanī considered the rate of precession to be equal to 90° in 100 years, which is the exact amount shown by the tables for the solar apogee in the Tables of London.[101] The author's detailed description of these tables agrees with the form they take in *L* and *T*, which both omit the sub-table for minutes found in copies of *Lc*8.[102]

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[94] Ibid., fols. 65^{r}–66^{r}.

[95] Ibid., fols. 59^{r}–63^{v}. Fol. 61^{r} contains tables for solar eclipse digits, which were drawn from the Toledan Tables. See Pedersen (Fritz) 2002: iv. 1458–1462 (JD11). See also ibid. ii. 530 (CbA.G41), for the text of a passage on parallax.

[96] This is Text VII noted in Mercier (1991: 19–20).

[97] See David Juste, "MS Cambridge, University Library, Kk 1.1 (1935)" (update: 02.03.2022), *Ptolemaeus Arabus et Latinus. Manuscripts*, URL=http://ptolemaeus.badw.de/ms/179.

[98] See, e.g., MS Cambridge, University Library, Kk.1.1, fol. 147^{r}: "In tab⟨ulis⟩ London⟨iensibus⟩ idcirco 30 dierum: secunda 31. Et incipiunt discordare idcirco 7 dierum. Ponunt enim 5 secunda ubi iste tantum 4 et videntur iste peccare, quia si addatur medius motus unius diei super medium motum 6 dierum, in quo concordant iste tabule et ille, proveniet numerus quem ille ponunt." Ibid.: "Tabule Lond⟨onienses⟩: 58 et videtur quod male et discepant in unitate usque in finem inclusive."

[99] This is true assuming that the text beginning *Quilibet trium planetarum aliorum* …, which

7 Editorial Principles

The following edition of the chapters in *Lc* is based on a collation of the three main witnesses, namely, *A*, *L*, and *S* (see § 3). It also takes into account an additional excerpt from *Lc*8 preserved in S_2. Manuscript *A* contains *Lc*12 twice, on fols. 13^{ra} and 19^{va}–b. I have collated the second of these copies on the grounds that it has fewer scribal errors than the first. The critical apparatus follows the principles outlined in part 1 (pp. 30–32). It records all significant variants between the aforementioned witnesses, ignoring only differences in spelling or minor slips of the pen. It also disregards *A*'s systematic habit of writing *igitur* for *ergo*. The spelling of words in the main text has frequently been normalized in accordance with classical conventions (e.g., *exstiterit* > *extiterit*).

The edition follows *A* and *L* in writing all larger numbers as Roman numerals. As was noted above (p. 206), the consistent use of Roman numerals was probably a feature of the archetype, which is why *S*'s use of Hindu-Arabic numerals will be ignored. Where *A* and/or *L* add a case ending to a Roman numeral, I have observed a bifurcated rule. For numbers below ten, I always write the full word (e.g., $\textsc{vi}^{te}$ > *sexte*), whereas numbers above ten appear as plain Roman numerals.

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takes up most of the following quire in the Cambridge manuscript (ibid., fols. 204^{r}–210^{v}, with the final piece of text attached to the end of *Circulus Solis* on fol. 203^{r-v}), is a separate work.

[100] Ibid., fols. 199^{v}–203^{r}.

[101] Ibid., fol. 193^{r}.

[102] Ibid., fol. 193^{r-v}.

For the tables for the solar apogee in *Lc*8, I have reconstructed their numerical content from the underlying parameter rather than collating the flawed or divergent copies in AC_2SS_2 and *LPT* (see pp. 315–317). For the table of solar and lunar velocities in *Lc*14, I have collated the copies in *L* and *S* while omitting the severely corrupt rendition in *A*. Where the numbers in *L* and *S* diverge, I have given preference to those shown in Pedersen's edition of the 'Toledan' version of the same table.[103]

Verbatim borrowings from identifiable sources, as found in *Lc*14 and *Lc*21–23, have been marked by italicizing the text.

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[103] Pedersen (Fritz) 2002: iv. 1412 (JA11).

ROBERTUS CESTRENSIS

Liber canonum: pars altera
Book of Canons, Part II

∵

Incipit pars altera huius operis, que videlicet ad meridiem urbis Londoniarum iuxta Albatem Haracensis sententiam per Robertum Cestrensem contexitur

⟨Lc1⟩

Promissa vero electe facultatis ad huius operis integritatem absolutio necnon ad ipsius integritatis constantiam continua tractatus nos admonet executio quatinus et de ratione canonum et per canones de inventione locorum planetarum iuxta Albatem Haracensis doctrinam hic in loco disseramus.

In primis igitur sciendum est quoniam hec pars huius operis ab anno domini MCL in prima kalenda mensis Martii, hoc est in fine hore sexte et initio septime primi diei mensis Martii, ponit initium, ut videlicet bisextilis diei intercalatio naturalem annorum residuorum seriem in anno bisextili non possit permutare. Naturalis namque annorum residuorum series in precedenti libro iuxta Ebenzaet Toletanum, cuius auctoritatem in eo libro secuti sumus, in omni anno bisextili iuxta quod dictum est permutatur. Licet enim anni domini per quos ille liber ad meridiem civitatis Toleti constituitur a Ianuario sumant initium, annus tamen bisextilis non ante sextam kalendam mensis Martii, in qua ipse terminatur, sumit initium. Unde in omni bisextili anno cum ad introitum tabularum annorum residuorum perventum fuerit, annus residuus cum quo ante Ianuarium in easdem tabulas ingreditur ante sextam kalendam Martii nullatenus non dimittatur. Ut igitur huius mutationis annorum varietas animum non conturbet artificis, liber iste in prima kalenda Martii ponit initium. Omnis namque bisextilis annus, a sexta kalenda Martii incipiens, antequam annus ab anno bisextili secundus a Martio incipiat in eadem sexta kalenda Martii terminatur. Quo fit ut in anno bisextili annus a Martio incipiens ante ipsius anni terminum diem bisexti in eius loco contineat.

Bisextilis autem diei ratio, licet in quibusdam annis necessaria videatur et utilis, tamen in annorum multitudine in diebus et mensibus et annis quantum ad quadrifidam bisexti intercalationem errorem generabit. Sol etenim in unius annualis ambitus spatio peractis CCCLX zodiaci circuli gradibus CCCLXV dies et quartam, id est horas sex, et unius hore partem nongentesimam et paxillum ulterius contra mundum nitendo videtur peragere. Unde,

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2 Haracensis] Harecensis *A* 5 promissa] premissa(?) *S* 8 Haracensis] Harecensis *A* 10 MCL] millesimo C^o^L^o^ *A* 14 Ebenzaet] Ebeneza et *A*; Ebenza et *S* 22 conturbet] turbet *A* 25 sexta] VI *S* 31 spatio] peracto *add. S*

Here begins the other part of this work, namely, the one composed by Robert of Chester for the meridian of the city of London according to the doctrine of al-Battānī of Raqqa

⟨Lc1⟩

The promised completion of the chosen skillset [sc. of astronomical computation] admonishes us, for the sake of the integrity of this work—and indeed, [so does] the continued execution of the treatise, for the sake of the persistence of this integrity—to discuss in this place the method of the tables according to doctrine of al-Battānī of Raqqa and their use in finding the positions of the planets.

The first thing to know, then, is that the present part of this work places the beginning on 1 March 1150, namely, at the end of the sixth and beginning of the seventh hour of the first day of March, which is done to ensure that the intercalation of the bissextile day in a bissextile year cannot alter the natural sequence of residual years. For in the preceding book according to Ibn Ṣāʿid the Toledan, whose authority we followed in this book, the natural sequence of residual years is altered in every bissextile year in the manner just mentioned. For although the years AD that are used in arranging this book for the meridian of the city of Toledo take their beginning from January, the bissextile year does not begin before the sixth before the kalends of the month of March, which is [also] when it ends. Whence in every bissextile year, when we have arrived at entering the tables for residual years, the residual year that was used to enter these tables before January shall by no means be abandoned before the sixth before the kalends of March. To ensure, therefore, that the difference wrought by this alteration of years does not confuse the practitioner's mind, the present book places the beginning on 1 March. For every bissextile year begins on the sixth before the kalends of March [and] ends on the same [day] before the second year from the bissextile year can begin from March. This way it is [guaranteed] that in a bissextile year a year beginning from March contains the bissextile day in its [proper] position before the end of this same year.

The principle of the bissextile day, however, though it may seem necessary and useful with respect to a certain year-span, will over larger numbers of years nevertheless generate an error of days, months, and years, as far as the bissextile intercalation in every fourth [year] is concerned. For during one annual cycle, which corresponds to the completion of 360° of the zodiacal circle, the Sun appears to complete 365 days and the fourth [part], which is six hours, as well as 1/900th of one hour and another small bit while advancing against [the direction of] the world. It follows that if the all the days of

si omnium dierum anni unius cum prefatis minutiis omnibus zodiaci circuli gradibus equa fiat distributio, LIX minuta et octo secunda in singulis diebus, hoc est in XXIIII horis, Solem posse peragere proculdubio reperies. In eius igitur ipsius singulis diurnis motibus LII secunda sui gradus Sol contra mundum nitendo ad perfectionem unius gradus videtur relinquere. Que scilicet secunda iuxta numerum graduum zodiaci circuli sumpta decem et octo milium et septingentorum viginti secundorum adimplent numerum. Ex his ergo omnibus secundis, si horas et dies integros velimus conficere, ipsa quidem decem et octo milia septingenta XX secunda per secunda unius hore primum dividantur. Quod enim inde provenerit horas integras tot secundorum ostendet. Reliquum vero secunda remanent. Si igitur has horas per numerum horarum unius diei diviseris et horas et dies integros tot secundorum optinebis.

Exempli gratia: decem et octo milia septingenta viginti secunda per secunda unius hore, id est per centum quadraginta octo secunda, divido et ex divisione centum viginti sex horas colligo. Quas cum per numerum horarum unius diei, id est per XXIIII, divido, quinque dies integros et sex horas ex divisione conficio. Ex prefatis ergo omnibus secundis dies quinque, horas sex, septuaginta duobus secundis remanentis reperio, que videlicet secunda nongentesimam partem et insuper duodecim partes ex quinquaginta quatuor milibus partium unius hore continent. Que scilicet minutie in processu temporis dies annualis ambitus Solis, ut supradictum est, permutabunt.

Cur autem in hoc libro annorum domini per XXVIII et XXIX et XX fiat collectio, hec est ratio. Anni vero domini, quamvis a Martio incipiant, ipsi tamen sunt solares. Solares namque anni a principio Ianuarii incipiunt et in fine Decembris terminantur. Cum igitur annus solaris CCCLXV dies et quartam diei partem, id est sex horas, optineat, si ex omnibus his diebus septimanas velimus efficere in uno anno solari LII septimanas cum uno die residuo inveniemus, per quam videlicet kalendarum XII mensium diversa fiet inchoatio. Oportuit ergo ut talis annorum fieret collectio qua scilicet nullius minutie horarum aut dierum diversa sequeretur mutatio. Per XXVIII igitur annos domini colligimus quoniam in naturali numerorum serie ante hunc numerum nullus reperitur numerus cuius collectioni minutie horarum aut dierum diversa non sequatur mutatio. Cum enim in uno anno solari LII ebdomade et una dies habeantur, si ipsas cum suo die sequenti

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34 omnium] omni *AS* 39 sumpta] hoc est multiplicata *add. S* 49 colligo] collige *S* 50 XXIIII] viginti quatuor *S* ‖ divido] diviso *A*; divisio *S* 52 videlicet] et *add. AS* 53 et] etiam *A* ‖ duodecim] XII *A* 53–54 quatuor] IIII *A* 58 Solares] Solaris *A* 60 id est] *om. S* 65 quoniam] *om. S* 66 hunc] nunc *S*

one year together with the aforementioned fractions are equally distributed over all the degrees of the zodiacal circle, you will no doubt find that the Sun is capable of completing 0;59,8° per day, which is the same as per 24 hours. With each of its diurnal motions, the Sun, as it advances against [the direction of] the world, can therefore be seen to be 52 seconds of a degree short of completing one degree. These seconds, if they are multiplied by the number of degrees in the zodiacal circle, fill up 18,720 seconds. If we wish to make hours and whole days from all these seconds, one must accordingly first divide these 18,720 seconds by the seconds contained in one hour. For the result will show the whole hours corresponding to this many seconds. But what stays behind as the remainder are seconds. If you divide these hours by the number of hours in one day, you will obtain both the hours and the whole days contained in this many seconds.

For example: I divide 18,720 seconds by the seconds in one hour, which are 148 seconds, and gather 126 hours from this division. Dividing these by the number of hours in one day (i.e., by 24), I make 5 whole days and 6 hours from this division. From all the aforementioned seconds, I accordingly find 5 days, 6 hours, with 72 seconds remaining, which evidently comprise 1/900th as well as 12/5400 of one hour. With the progress of time, these fractions will alter the days of the Sun's annual cycle, as has been said above.

The reason, however, why the years AD are in this book grouped by 28 and 29 and 20 is as follows: the years AD, though they may begin from March, are nevertheless solar. For solar years are those that start at the beginning of January and finish at the end of December. Now, given that the solar year comprises 365 days and the fourth part of a day (i.e., 6 hours), if we wish to derive weeks from all these days, we will find in one solar year 52 weeks with one remaining day. This [remaining day] evidently causes the beginnings of the twelve months to change [with respect to the week]. It was therefore necessary to group the years in a way that would not entail changes of any fraction of hours or days [with respect to the week]. We consequently group the years AD by 28, seeing as there is no earlier number in the natural sequence of numbers such that using it to group [the years] would not result in a change of a fraction of hours or days [with respect to the week]. For given that one solar year has 52 weeks and one day, if we multiply these [weeks]

in xxviii duxerimus, mille quadringentas lvi ebdomadas necnon et xxviii dies reperiemus. Et si xxviii dies per septem diviserimus, iiii quidem ebdomade absque ullo die residuo inde provenient. Si igitur has iiii ebdomadas mille quadringentis lvi ebdomadis addidero, mille quadringente lx ebdomade absque omni hora et die residuo in hac tota summa invenientur. Unde necessaria ratione anni vicesimi octavi [!] principium ad eandem feriam qua videlicet primus ab eo annus ingressus est redire oportet. Hac igitur ratione circulus solaris in xxviii annis terminatur.

Et similiter, quoniam anni domini a mense Martio, uti iam dictum est, incipiunt, xxix annis annos xx adicio fiuntque xlix, ex quibus videlicet duo milia quingentas xlviii ebdomadas absque omni hora et die residuo colligo. Hec est igitur ratio cur anni domini per xxviii et xxix et xx in hoc libro colliguntur.

Non dissimili quoque ratione in canonibus Arabum anni lunares per xxx colliguntur. Annus namque lunaris ex cccliiii diebus integris et quinta ac sexta parte unius diei constare probatur. Nam et Arabes diem unum in xxx partes equales, quas trigesimas vocant, solent dividere. Quod ideo fecerunt, quoniam trigenus numerus quintam ac sextam partem ante omnem numerum optineat. In quinta ergo ac sexta parte unius diei iuxta trigenam diei divisionem xi trigesime continentur. Quamobrem in tribus annis lunaribus xxxiii trigesime, id est dies integra cum tribus trigesimis oritur. In annis vero sex, dies duo xxx sex oriuntur. In xii dies quatuor, ⟨xxx⟩ duodecim. In annis xviii dies sex, xxx octodecim. In xxiiii dies octo, xxx xxiiii. In triginta annis dies decem et xxx trigesime, que scilicet diem integrum absque trigesima efficiunt. Quem scilicet si decem diebus ante collectis addidero, erunt dies xi. Et sic in xxx annis lunaribus ex quinta ac sexta parte unius diei, que scilicet xi sunt trigesime, dies xi absque omni minutia oriuntur.

Unde quemadmodum ciclus solaris in anno xxviii, qui scilicet bisextilis est, terminatur, ita et ciclus lunaris in xxx annis lunaribus finitur. Unde etiam duodecimus mensis Arabum, qui Dulhige dicitur, xxix optinens xxx dies in eodem anno optinebit. Qua in re sciendum est quod quemadmodum ciclus lunaris in xxx annis lunaribus perficitur, ita solaris ciclus in xxviii annis solaribus absque omni horarum et dierum minutia terminatur. Unde

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70 xxviii] xxv *A* 72 ebdomadis addidero] ebdomadas addido *A* 77 Et similiter] Similiter et *A* ‖ domini] dicuntur *A* 78 videlicet] et *add. A* 79 quingentas] quingentos *A* 83 ac] hac *AS* 90 duo] vero *S* 91 octodecim] est *add. A* ‖ triginta] vero *add. A* 94 sic] sicud *A* 98 etiam] *om. S*

together with the day that follows them by 28, we will find 1456 weeks as well as 28 days. And if we divide 28 days by 7, the result will be 4 weeks without any remainder of days. Consequently, if I add these 4 weeks to 1456 weeks, the whole sum will be found to be 1460 weeks without any hour and day remaining. It therefore follows by necessity that the beginning of the 28th [!] year returns to the same day of the week on which the first year from [which it is counted] began. This is the reason why the solar cycle finishes after 28 years.

And by the same token, since the years AD begin from the month of March, as has already been said, I add 20 years to 29 years and they become 49, from which I derive 2548 weeks without any hour and day remaining. This is the reason why the years AD in this book are collected by 28 and 29 and 20.

According to a similar principle, the lunar years in the tables of the Arabs are grouped by 30. For it is known to be true that the lunar year comprises 354 days as well as the fifth and the sixth part of one day. For the Arabs are wont to divide one day into 30 equal parts, which they call 'thirtieths'. They do this because the number 30 is the first number to comprise the fifth as well as the sixth part. According to the division of the day into thirtieths, the fifth and the sixth part of one day [jointly] contain 11 thirtieths. On account of this, 3 lunar years give rise to 33 thirtieths, that is, a whole day with 3 thirtieths. But 6 years give rise to 2 days [and] 6 thirtieths; 12 to 4 days [and] 12 thirtieths; 18 years to 6 days [and] 18 thirtieths; 24 to 8 days and 24 thirtieths; 30 years to 10 days and 30 thirtieths, which amount to a complete day without any thirtieth. If I add this [day] to the 10 days gathered before, the result will be 11 days. And thus 11 days without any fraction arise in 30 lunar years from the fifth and sixth part of one day.

It follows that just as the solar cycle finishes in the 28th year, which is bissextile, so the lunar cycle ends after 30 lunar years. Another consequence is that the 12th month of the Arabs, which is called Dhu al-Hijjah, will in this year comprise 30 days [though it normally] comprises 29 days. One should know in this regard that just as the lunar cycle is completed in 30 lunar years, so the solar cycles finishes after 28 solar years without [leaving] any fraction of hours and days. It is hence accepted as a necessary consequence that

siquidem necessario accipitur quod annorum solarium per XXVIII, lunarium vero per triginta in canonibus huius artis in tempus futurum ab initio operis facienda est collectio.

Nunc vero sciendum est quoniam annis domini MCXLIX completis ab anno domini MCL finitis VI horis primi diei mensis Martii liber iste sumpsit initium. Iuxta hunc quidem terminum radices planetarum VII et capitis Draconis Lune in capitibus tabularum medialium huius libri, ut decet, signavimus. Radices vero planetarum sunt eorum loca iuxta eorum medios cursus in initio operis ad meridiem cuiuslibet loci in signis, gradibus, minutis atque secundis certa indagatione reperta. Supra hec namque loca tamquam supra radicem aut structure fundamentum adiectiva progressionis eorum motus per annorum collectionem in tempus futurum quasi quedam fit constructio, ut videlicet in quodlibet tempus futurum ab initio operis planetarum VII locorum medialium certa fiat inventio.

Quoniam igitur per XX supra XXIX in hoc libro annorum fit aggregatio, annus ab operis huius initio vicesimus annus domini MCLXIX erit. Si enim supra MC quadraginta novem annos domini ante initium huius operis iam transactos XX annos addidero, MCLXIX annos optinebo. Et qui quadragesimus annus ab eodem termino extiterit, annus domini MCLXXXIX erit. Et sic deinceps per vigenam collectionen numeri in infinitum possunt excrescere. Ob hanc igitur causam singulis collectionibus novenarius apponitur, ut videlicet annus cuiusque collectionis qualiscumque extiterit quotuscumque idem annus ex annis domini fuerit servata collectionum serie dinoscatur.

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104 collectio] Sciendum est quod primus numerorum annorum collectorum in tabulis mediorum cursuum et ubicumque ponuntur anni collecti debet secundum istos canones esse 20, secundus 40, tertius 60, et sic ulterius semper addendo numero precedenti 20 et habebitur proximus sequens. Quod si primus numerus annorum collectorum sit 29, sequentibus per crementum 20 ascendentibus tantum auferendi sunt 1140. Et idem erit omnino sicut per alium modum. Sciendum est etiam quod si primus numerus esset 1149 et secundus 1169 et sic ultra nichil esset omnino addendum vel sulethendum [*sic*]. Hec omnia necessario convincuntur ex doctrina huius canonis et quantitate mediorum motuum positorum contra annos expansos, sicut patet scienti rationem compositionis tabularum et causam. Hec autem circa que scripsi habent veritatem si queratur medius motus ad aliquod annum Christi qui sequitur 1149 et ad nullum precedentem. Sed nec ad se ipsum, quia in fine illius fuerit medius motus qui ponitur in radice. Domine. Th⟨?⟩ iterum(?) et incertum valent(?). *add. S*   107 quidem] igitur *A*   109 planetarum sunt] sunt planetarum *A*   110 in] *om. S* ‖ gradibus] atque *add. a.c. A*; in *add. S*   113 quasi] *gem. S*   118 huius] unius *S*   120 MCLXXXIX] M.C. octogesimus nonus *A*   122 apponitur] opponitur *A*   124 collectionum] *om. A*

while one must group the solar years by 28 in the tables of this art from the beginning of the work into the future, the lunar years [must be grouped] by 30.

But now one should know that that this book takes its beginning from AD 1150, at the end of 6 hours of the first day of the month of March, with 1149 AD years completed. This is the date according to which we have designated, as is proper, the roots of the seven planets and the lunar ascending node at the heads of the tables of mean motion [contained in] this book. The roots of the planets, however, are their positions according to their mean courses at the beginning of the work, as found by reliable investigation for the meridian of a given location [and expressed] in signs, degrees, minutes, and seconds. For using these positions in the manner of a root or the foundation of some building, one constructs, as it were, in an additive sense the future advance of their motions by grouping years together, so as to enable finding the mean positions of the seven planets for any future date after the work's starting point.

Since the years in this book are accumulated by steps of 20 on top of 29, the 20th year from the beginning of this work will consequently be AD 1169. For if I add 20 years to the 1149 years AD that have already gone before this work's starting point, I will obtain 1169 years. And the 40th year from this starting point will be AD 1189. And [continuing] onwards in this manner, the numbers can grow unto infinity in steps of 20. This is the reason why the number 9 is placed before each grouping, namely, so that one may discern for any year of any grouping the corresponding year AD, [provided the] sequence of groupings is preserved.

⟨Lc2⟩ *De annorum conversione et qualiter quidam ex aliis eliciuntur*

Annorum quidem cuiuscumque nationis ratio anni solaris est dierum variata coniectio. Quidam namque a Ianuario, quidam vero a Martio, quidam a Septembre et Octobre, quidam etiam a prima Lune visione post coitum, quidam et a coniunctione Solis et Lune principium anni constituunt atque Solis annualem ambitum per menses equales et inequales duodena divisione annos in maiores et in minores variando distinguunt. Et quoniam ab annis solaribus, qui videlicet a Ianuario et Martio incipunt, liber iste per annos domini constitutus sumpsit exordium, propter eorum tantum diversitatem de annorum conversione docili sermone tractemus, ut annorum unius generis in annos alterius generis facta conversione per alterutros alterutrius generis annos ad eorum canones facilior fiat introductio.

Prima igitur eorum conversionis est agnitio quod integralis sive diminutiva omnis annorum fit conversio. Tunc enim annorum integralis est conversio quotiens dierum in minutias nulla fit dissolutio. Econtra vero, si dierum in minutias ulla fiat disiunctio, diminutiva quidem annorum illa erit conversio. Qualiter vero dierum in minutias fiat vel non fiat disiunctio, ipsa annorum nos docebit conversio. Quotquot igitur annos vertere volueris, ipsos in numerum dierum unius anni sui generis primum multiplica et totam multiplicationis summam per numerum dierum unius anni, eorum videlicet in quos ipsos convertis, partire. Quotquot enim divisiones habueris, totidem annos iam conversos procul dubio optinebis.

Sed et hec ratio de annorum conversione quos nulla diei comitatur minutia sufficiens habeatur. De conversione namque annorum quos diei comitatur minutia aliter agendum est. Annus namque solaris in ter centum LXV dies atque unius diei quartam partem distinguitur et annus lunaris in CCCLIIII dies atque unius diei quintam ac sextam partem certa dimensione metitur. Si igitur annos solares in annos lunares vel econverso vertere volueris, utriusque generis annos in genus eiusdem comitantis minutie multiplica et totam multiplicationis summam per minutias eiusdem generis dierum unius anni, eorum scilicet in quos ipsos convertis, partire.

Quod ut manifestius fiat hoc docetur exemplo. Tres siquidem annos solares assumo ipsosque hac ratione in annos lunares converto. Ternarium ita-

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126 De … eliciuntur] *mg. A* 127 ratio] est *add. A* ‖ anni] annis *AS* 128 coniectio] coniescio *S* 129 etiam] autem *A* 130 quidam … Lune] *om. A* 132 distinguunt] distingunt *AS* 134 propter] et per *A* ‖ tantum] termini *A* 138 quod] qui *A* 140 in] *om. A* ‖ dissolutio] dissolatio *A* 141 ulla] illa *A* ‖ annorum] allorum *S* 142 in minutias] minuties *A* 143 nos docebit] docebit nos *A* 144 dierum] in *add. A* 145 videlicet] et *add. A* 148 nulla] nullam *S* ‖ diei] die *A* 152 quintam] hoc est in VI tricesimas *add. A* ‖ ac] et *A* 158 assumo] a summo *A* ‖ hac] ac *A* ‖ lunares] *om. S*

⟨Lc2⟩ *On the conversion of year*[*-types*] *and how one can be extracted from the other*

The year-type of a given nation is the variegated count of days in a solar year. For certain [nations] begin the year from January, others from March, others from September and October, yet others from the first sighting of the Moon after conjunction, others instead from the conjunction of the Sun and Moon; and they partition the annual cycle of the Sun into equal and unequal months by dividing it by 12, while alternating between shorter and longer years. And since this book, which is based on years AD, takes its beginning from solar years that begin from January and March, their difference shall be the only one we take into account as we deal with the conversion of years in an easily taught lesson, so as to make it easier to use years from either type to enter their respective tables after having converted years of one type into years of the other type.

When it comes to converting them, the first thing to know is that every conversion between years is either complete or diminished. The conversion of years is complete in cases where no days are dissolved into fractions. If, on the other hand, any days at all are broken up into fractions, this conversion of years will be diminished. But the manner in which days are broken up into fractions, or not, is something the conversion of years itself will teach us. However many years you wish to convert, you must first multiply them by the number of days in one year of this type and divide the whole product by the number of days in one year of those into which you convert them. For the number of times by which [this product] can be divided will no doubt give you the number of already-converted years.

But this method of converting years shall be considered sufficient for [years] that are not accompanied by any fraction of a day. For when it comes to years that are accompanied by a fraction of a day, a different approach must be taken. The solar year, for instance, is partitioned into 365 days and the fourth part of a day and the lunar year is reliably estimated to be 354 days and the fifth as well as the sixth part of a day. Therefore, if you wish to convert solar into lunar years, and vice versa, you must multiply the years of either type by the type of its accompanying fraction and divide the whole product by the fractions of the same type [that are contained] in the days of one year of those into which you convert them.

In order to make this clearer, it [shall be] demonstrated with the following example. I take three solar years and convert them into lunar years using the following method. I multiply the number 3 that corresponds to the number

que qui annorum est numerus in MCCCCLXI, qui omnium quartarum omnium dierum unius anni solaris est numerus multiplico ipsosque tres annos in genus minutie, que scilicet est quarta pars unius diei, hac ratione converto. Huius igitur multiplicationis summam, id est ĪĪĪĪCCCLXXXIII, per MCCCCXVI, que sunt quarte partes dierum integrorum unius anni lunaris, divido fiuntque ex tribus annis solaribus anni lunares tres, XXXIII dies, III quarte unius diei, que sunt hore XVIII.

Amplius, si annos solares in annos lunares vertere volueris, quotquot annos sumpseris ipsos in dies unius anni solaris primum multiplica atque toti dierum summe quartas ipsos annos comitantes per quatuor divisas et in dies integros collectas aggrega. Quod cum feceris, hos omnes dies in XXX multiplica fientque horum dierum partes trigesime. Quas cum per X̄DCXXXI diviseris ex tot annis solaribus anni fient lunares. In uno namque anno lunari X̄DCXXXI partes trigesime unius diei continentur.

Quod si annos lunares in annos solares convertere volueris, ipsos annos lunares in numerum dierum unius anni lunaris primum multiplica. Inde vero eosdem annos in XI multiplica et per XXX divide, ut quintas et sextas ipsos annos comitantes in dies integros colligas et collectos summe priori dierum adicias. Hanc ergo dierum integram summam in IIII multiplica et per MCCCCLXI divide et sic annos lunares in annos solares converte.

Exempli gratia: tres annos lunares in CCCLIIII multiplico, hic enim est numerus dierum unius anni lunaris, ut fient MLXII. Item ipsos tres annos in XI duco fiuntque XXXIII, quas scilicet cum per XXX divisero unum diem integrum colligo. Quem videlicet priori summe dierum adicio fiuntque dies MLXIII et unius diei decima. Hanc igitur summam dierum quadruplico et dies in quartas dissolvo fiuntque ĪĪĪĪCCLII dierum quarte. Quas cum per MCCCCLXI divisero ex tribus annis lunaribus duos annos solares, menses X, dies XXIX colligo. Omnis enim omnium minutiarum unius generis per invicem divisio earundem integrorum fit restitutio. Et hoc est quod superius iam diximus, qualiter videlicet dierum in minutias vel fiat vel non fiat disiunctio.

Quod autem annos lunares in XI ducimus quodque inde provenit per XXX dividimus hac ratione etiam intimamus. Cum enim annus lunaris dies CCCLIIII ac unius diei quintam et sextam partem optineat, dies siquidem in XXX partes equales dividitur, cum ante trigenum numerum nullus inveniatur numerus qui quintam et sextam partem integralem possit optinere. Habet

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160 tres] III *A* 161 genus] cicius *A* 162 ĪĪĪĪCCCLXXXIII] minutiam CCC^{a}.LXXX.III^{a} *A* 164 tres] III *A* 167 primum] ipsum *A* 170 horum dierum] dierum horum *A* ‖ X̄DCXXXI] 621 *S* 171 fient] fiant *A* 172 X̄DCXXXI] 621 *S* 181 divisero] divisio *S* 185 menses X] mensesque *A* 188 qualiter] quotiens *AS* ‖ in] *om. A*

of years by 1461, which is the number of all fourths of a day [contained in] all days of one solar year, and thereby convert these 3 years into [their] type of fraction, namely, the fourth part of one day. I divide the product, which is 4383, by 1416, which are the fourths of the complete days in one lunar year, and 3 solar years become 3 lunar years, 33 days, and 3 fourths of one day, which are 18 hours.

Furthermore, if you wish to convert solar years into lunar years, you must first multiply however many years you have taken by the days in one solar year and add to the whole sum of days the fourths that accompany these years, after they have been divided by 4 and grouped together as complete days. Having done this, you must multiply all these days by 30 and they will become the thirtieths of these days. Once you have divided these by 10,631, this many solar years will become lunar ones. For one lunar year comprises 10,631 thirtieths of a day.

But if you wish to convert lunar years into solar years, you must first multiply these lunar years by the number of days in one lunar year. Next, you must multiply these years by 11 and divide by 30, so you can group the fifths and the sixths that accompany these years into whole days and add [the resulting number] to the previous sum of days. Multiply, therefore, this whole sum of days by 4 and divide [the result] by 1461 and in this fashion convert lunar years into solar years.

For example, I multiply 3 lunar years by 354—for this is the number of days in one lunar year—so that they will become 1062. I also multiply these 3 years by 11 and they become 33. Once I have divided these by 30, I collect one whole day. I add [this day] to the previous sum of days and they become 1063 and one tenth of a day. I consequently multiply this sum of days by 4 and dissolve the days into fourths and they become 4252 fourths of a day. Once I have divided these by 1461, I collect from [these] 3 lunar years 2 solar years, 10 months, 29 days. For each division of all fractions of one type by those of another leads to a restitution of the same integers. And this is what we already mentioned above [when referring to] the manner in which days are either broken up into fractions or not.

But that we must multiply lunar years by 11 and divide the result by 30 is something we shall also relate in the following way. For since a lunar year comprises 354 days and the fifth and the sixth part of one day, the day is consequently divided into 30 equal parts, seeing as there is no number before 30 that can comprise both the fifth and the sixth part as an integer. For the num-

enim trigenus numerus quintam sui partem senarium et sextam quinarium. Sed quinarius cum senario iunctus undecimum adimplet numerum. Undenus ergo numerus quintam et sextam partem numeri trigeni continet. In undeno igitur numero undecim trigesime, que videlicet quintam et sextam partem trigeni numeri constituunt, continentur. Ob hoc igitur annos lunares in XI ducimus ut quot annos assumimus etiam totiens XI trigenas, que quintam et sextam partem diei continent, assumamus. Has ergo, cum ad trigenum numerum vel plus excreverint, per XXX dividimus ut ex eis dies integros restauremus. Triginta enim unius diei trigesime diem integrum componunt.

His igitur rationibus cuiuscumque generis anni extiterint in annos alterius generis possunt converti. Sed etiam sciendum est quoniam minutie que post dierum collectionem supervenerint, si ad uni diei medietatem non excreverint, negligantur; si autem, pro die integro in summa dierum computentur. Nunc vero qualiter quidam eorum abinvicem eliciuntur brevi oratione doceamus.

⟨Lc3⟩ *De extractione annorum unius generis ab annis alterius generis*

Cum igitur annos unius generis per annos alterius generis quis invenire voluerit, eorum differentia in annis, mensibus, diebus et dierum minutiis quotacumque ipsa fuerit notanda est. Hec enim differentia annis qui plures fuerint subtracta annos pauciores ostendit. Que etiam si annis paucioribus adiecta fuerit annos plures ipsa componit. Sed et hec annorum abinvicem extractio maxime ad nos pertinet quorum videlicet una eademque dies alicuius mensis solaris ponit initium. Et ne erroris nebula lectoris obumbretur intentio, annos ere et annos domini in exemplum proponimus. Prima namque kalenda mensis Ianuarii utriusque annis ponit initium.

Si igitur annos domini per annos ere aut annos ere per annos domini quis invenire voluerit, eorum differentia prius notanda erit. Est autem eorum differentia XXXVIII annorum quantitas quibus anni ere annos domini precedunt. Igitur XXXVIII annis ere subtractis, quicquid ex annis ere residuum fuerit annos domini indicabit. Quod si eundem annorum numerum, id est XXXVIII, annis domini aggregaveris, annos ere procul dubio accumulabis. Quod si annum bisextilem in annis ere vel annis domini invenire volueris, utrosque annos per quaternarium divide. Numerus namque qui ex eis minus quatuor residuus fuerit pro sui quantitate annum bisextilem indicabit. Unitas ergo primum, binarius secundum, ternarius tertium post bisex-

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195 undecimum] unde unum *AS* 199 ut] in *S* 201 excreverint] exercuerint *AS* 204 etiam] et *A* 205 que] *om. A* 209 De … generis] *mg. A* 211 diebus] dierum *A* 213 etiam] et *A* 215 videlicet] et *add. S* 222 Igitur] S(?) *A* 228 binarius] binarii *A*

ber 30 has 6 as its fifth part and 5 as its sixth part. Yet 5 joined together with 6 fill up 11. The number 11 consequently contains the fifth and the sixth part of the number 30. The number 11 accordingly contains 11 thirtieths, which evidently make up the fifth and sixth part of 30. This is the reason why we multiply lunar years by 11, so that for any number of years that we take we can also take the corresponding multiple of 11 thirtieths, which comprise the fifth and the sixth part. If these grow to 30 or more, we divide them by 30 to rebuild them into whole days. For 30 thirtieths of one day make a whole day.

According to these principles, then, the years of one type, whatever it may be, can be converted into the years of another type. But one should also know that if the fractions that are left after days have been collected do not exceed one-half of a day, they are neglected. If, on the other hand, they do [exceed], they are reckoned for a whole day as part of the total of days. But now let us teach in a brief presentation how certain [year-types] are derived from each other.

⟨Lc3⟩ *On how to extract years of one type from the years of another type*

If someone wishes to find the years of one type on the basis of the years of another type, one must take note of the difference between them, whatever it may be, according to years, months, days, and fractions of days. For if this difference is subtracted from the larger number of years, it will show the smaller number of years. Also, if it is added to the smaller number of years, it creates the larger number of years. But the one type of mutual extraction of years that is most relevant to us is the one pertaining to years that begin from the same day of some solar month. And to keep the reader's thought from being darkened by the fog of error, we shall use as an example the years of the Era and the years AD. For both year[-types] begin on 1 January.

Consequently, if someone wishes to find the years AD on the basis of years of the Era or the years of the Era on the basis of years AD, one will first have to take note of their difference. The size of their difference, however, is 38 years, by which the years of the Era precede the years AD. Once 38 years have been subtracted from the years of the Era, whatever remains of the years of the Era will accordingly reveal the years AD. But if you add the same number (i.e., 38 years) to the years AD, you will doubtlessly generate years of the Era. But if you wish to find the bissextile years according to years of the Era or years AD, you must divide either [number of] years by 4. For the number lower than 4 that remains from them will reveal the bissextile year according to its size. The number 1 will consequently show the first year after the bissextile

tum annum ostendit. Quod si annorum quaterna divisio in quatuor absque residuo terminata fuerit, in anno bisextili te esse cognoscas. Hoc etiam addito ut annis ere quotquot ipsi fuerint duos annos semper adicias. Et de his hactenus.

Ad extractionem vero annorum diversorum abinvicem quibus videlicet diversa diversorum mensium dies ponit initium, annorum lunarium ab annis domini extractionem in exemplum proponimus. Cum igitur annos Arabum, qui sunt lunares, et eorum menses et dies ex annis domini et mensibus et diebus per eorum differentiam elicere volueris ex annis domini completis DCXXI, qui eorum sunt differentia, diminuas. Numerum igitur annorum residuorum, quodcumque ille fuerit, in CCCLXV dies et unius diei quartam [!] hoc modo multiplica ut tot annorum dies integros colligas. Inde vero eundem numerum annorum residuorum per quatuor divide et quot divisiones provenerint, tot dies omnibus diebus prius ex multiplicatione collectis adice. Et sic ipsos annos in CCCLXV dies et unius diei quartam dissolves. Si vero ex quaterna divisione binarius aut eo minus remanserit, negligatur. Si vero plus, pro dierum integrorum uno die ceteris diebus apponatur.

Ex hoc igitur numero integrorum dierum CXCV dies subtrahe eique quod residuum fuerit omnes dies anni solaris non completi a prima die Ianuarii inchoando in diem quem volueris adiunge. Quibus executis, hoc omnes dies in XXX multiplica et multiplicationis summam per decem milia DCXXXI divide. Quotquot enim divisiones habueris, tot proculdubio annos lunares completos optinebis. Quodque residuum fuerit per XXX divide eruntque dies. At si supra trigenam divisionem XV aut eo minus aliquid remanserit, negligatur. Si vero maius, una dies reliquis diebus adiciatur. Ex his igitur diebus, XXX uni, alteri vero XXIX dies distribuendo, menses Arabum, qui sunt lunares, constitue, ut annos Arabum et menses et dies ex annis domini et mensibus et diebus possis elicere. Nunc vero ad sequentia transeamus.

⟨Lc4⟩ *Qualiter opifex astronomus ad huius artis officium per tabulas canonum omnium ingrediatur*

Hactenus de annorum conversione et eorum abinvicem extractione, prout huius operis ratio postulat, predocuimus. Nunc vero qualiter per ipsos ad eorum canones lectori fiat introitus etiam brevi ratione doceamus.

238–240 annorum … tot] *om. per hom. A* 242 provenerint] proveneri t *S* 246 integrorum dierum] *om. A* 253–254 diebus] *om. A* 255 domini et] dominique *S* 256 possis] possit *S* 257–258 qualiter … ingrediatur] *mg. A* 261 lectori] lectorum *A*

[year], the number 2 the second, the number 3 the third. But if the division of years by 4 ends on 4 without a remainder, you shall know that you are in a bissextile year. Let it also be added that you must always add two years to the years of the Era, however many there may be. And this much [shall suffice] on this subject.

But when it comes to the mutual extraction of different types of years that begin on different days of different months, we shall put forward by way of example the extraction of lunar years from years AD. If you wish to derive years of the Arabs, which are lunar, and their months and days from years AD and [their] months and days based on their difference, you must subtract 621, which are their difference, from the completed years AD. The number of years remaining, whatever it may be, you must multiply by 365 days and one fourth of a day [!] in order to obtain the complete days contained in this many years. Next you must divide the same number of years remaining by 4 and add the number of days that corresponds to the quotient to the days that have previously been obtained via multiplication. And in this manner you will dissolve these years into 365 days and one fourth of a day. But if the remainder after division by 4 is 2 or less, it must be neglected. If, on the other hand, it is more, it must be added as one whole day to the other days.

Subtract 195 days from this number of whole days and add to the remainder all the days of the incomplete solar year starting from 1 January [and ending] at whatever day you wish. Having performed this operation, you must multiply all these days by 30 and divide the product by 10,631. For you will doubtlessly obtain as many completed lunar years as the number of times one can be divided by the other. And you must divide the remainder by 30 and the result will be in days. In case, however, the remainder after dividing by 30 is 15 or less, it must be neglected. If, on the other hand, it is greater, one must add one day to the other days. And from these days you must construct months of the Arabs, which are lunar, by assigning 30 to one, 29 to the other, so that you can derive years, months, and days of the Arabs from years AD. But now let us proceed to the following [topics].

⟨Lc4⟩ *How the practicing astronomer can undertake the practice of this art using the tables of any given set* [*of tables*]

So far, we have given instructions on the conversion of years and their mutual extraction, insofar as the method of this work demands it. But now we shall also give concise instructions on how the reader can use these [years] to enter the corresponding tables.

Cum igitur lector huius artis ad canones ingressum habere voluerit, in primis cuius nationis sint anni per quos videlicet ipsi canones constituti sunt diligenti ratione addiscat. Inde vero utrum ipsi canones ab ipsorum annorum initio, seu ab ipsorum anno alio sumpserunt exordium non minus inquirat. Sed et iuxta quem numerum ipsorum annorum fiat collectio nullatenus indagare non pretermittat. His enim omnibus diligenti inquisitione prenotatis, omnia que ad huius artis officium pertinent, ut in sequentibus docebitur, facillime poterit pertractatre.

Unde sciendum est quoniam liber iste, qui per annos domini, licet non ab eorum initio, constitutus est, et diversum sibi ponit initium et diversam annorum collectionis suscipit rationem. Ea namque eius pars que ad meridiem civitatis Toleti constituitur a MCXLIX anno domini incipit et ab eodem termino annos domini per XXVIII colligens lineas annorum collectorum in mediis planetarum cursibus in tempus futurum extendit. Altera vero eius pars cuius videlicet ratio ad meridiem urbis Londoniarum contexitur ab anno domini MCL sumpsit exordium et ab hoc termino annos domini per vigenum coacervans numerum annorum collectorum lineas in tabulis planetarum medialibus in futurum tempus producit.

Quapropter, cum lector ad canones qui ab initio suorum annorum non incipiunt accedere voluerit, anno quo ipsi incipiunt prenotato tot annos annis illius nationis, cuius videlicet ipsi sunt anni super quos liber contexitur, auferat quot annos libri principium preterisse cognoverit, ut cum ipsorum annorum residuo, prout in sequentibus reperitur, canonum sibi pateat introitus. Quod si canones a principio annorum seu nationis inceperint, aliter agendum erit. Quod qualiter fieri debeat etiam in sequentibus docebitur.

Si igitur liber canonum per annos alicuius nationis constructus ab eorum initio initium sumpserit, quot anni et menses et dies, hore quoque et minuta a primo eorum in tempus presens preterierint investiget. Quos cum cognoverit, annos ante annum presentem completos per numerum collectionis eorum dividat, ut iuxta illud quod ex divisione provenerit cum quot collec-

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267 pretermittat] premittat *A* 269 poterit] potest *A* 273 MCXLIX] M^o.C^o.LXIX *A* 285 inceperint] inceperit *A* 287 constructus] constructas *A* 289–290 cognoverit] agnoverit *A* 290 annos] quos *add. A* ‖ presentem] iam *add. A*

If the reader of this art wishes to enter the tables, he first needs to determine by careful reasoning to which nation the years that were used to construct the tables in question belong. Next he must investigate to no less an extent whether these tables began from the start of these years or from some other year among them. But another thing he must by no means omit to track down is the number according to which these years are grouped together. For once all of this has been noted by means of careful investigation, he will be able with great ease to work out all of the things that pertain to the practice of this art, as will be taught in what follows.

One should accordingly know that this book, which was constructed on the basis of years AD, but not from their beginning, both employs different beginnings and accepts different ways of grouping the years together. For the part of it that is constructed for the meridian of the city of Toledo begins from AD 1149 and extends from this starting point the columns for collected years in [the tables for] the mean courses of the planets into the future by grouping the years AD by 28. Its other part, by contrast, which is composed for the meridian of the city of London, begins from AD 1150 and from this starting point stretches out the columns for collected years in the mean[-motion] tables of the planets into the future by piling up years AD based on the number 20.

Because of this, whenever the reader wishes to approach tables that do not start from the beginning of their years,[1] he must first take note of the year from which they begin [and then] subtract from the years of this nation—namely, the [nation] that uses the very years on whose basis the book is composed—as many years as he knows to have come before the book's beginning, so that the remainder of these years may reveal the [number] with which to enter the tables, as is found in the following [chapters]. But if the tables start from the beginning of the years or the nation in question, one must proceed differently. How this must be done will likewise be taught in what follows.

If a book of tables constructed according to the years of some nation takes its beginning from their beginning, he must find out how many years, months, and days as well as the hours and minutes have passed between the first [of these years] and the present time. Once he knows this, he must divide the years that have been completed before the present year by the number by which they are grouped together, so that the reader shall discern from the quotient the number of groupings by which one must enter the

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[1] That is, tables whose starting point does not coincide with the epoch of the relevant era.

tionibus in lineam annorum collectorum intrandum sit lector agnoscat. Nec minus et cum ⟨quot⟩ annis minus una collectione residuis et mensibus et diebus, horis quoque et minutis in eorum tabulas iuxta quod predocuimus esse intrandum agnoscat.

⟨Lc5⟩ *Qualiter cuiuslibet loci longitudo per eclipsim Solis et Lune inveniatur*

Cum igitur alicuius loci longitudinem sibi ignotam per eclipsim Solis vel Lune lector huius artis invenire voluerit, differentia horarum et earum partium quibus scilicet initium vel finis ponitur solaris seu lunaris eclipsis que et in sua et in altera regione, note scilicet longitudinis, accidit diligenti ratione investiget. Qua cum invenerit, differentie horas cum suis partibus in gradus convertat. His ergo gradibus simul collectis memorieque commendatis, si regio ignote longitudinis a regione note longitudinis occidentalis extiterit, ipsos gradibus note longitudinis alterius regionis auferat quodque residuum fuerit longitudinem sue regionis esse non dubitet. Si vero ipsa regio ignote longitudinis regioni note longitudinis orientalis fuerit, eidem gradus eidem note longitudini adiciantur et erit id ipsum.

Utrum etiam ignote longitudinis regio regioni note longitudinis orientalis seu occidentalis fuerit ex principio vel fine eclipsium que in utraque regione accidit facile perpenditur. Si enim a meridie vel a media nocte diei eclipsis usque ad eclipsis initium vel finem in regione note longitudinis plures, in ignote vero longitudinis regione pauciores hore cum suis partibus collecte fuerint, ipsa quidem regio ignote longitudinis regioni note longitudinis occidentalis erit, et econverso.

Sed et horarum partes hac ratione in gradus convertuntur. Aut igitur ipse partes horarum in xv ducantur et per lx dividantur, aut etiam, si libeat, iste partes sine multiplicatione per quatuor partiantur, ut et ipse partes gradus efficiantur. Hora namque equalis, cum ex xv gradibus equalibus habeat existere, quindecies lx, id est nongenta minuta circuli equinoctialis videtur optinere. Que scilicet, si in lx partes equales, quas minuta unius hore vocant, divisa fuerint, quelibet pars earum quarte parti unius gradus, id est minutis

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296–297 Qualiter … inveniatur] Qualiter cuiuslibet loci longitudo inveniatur per eclipsim Solis et Lune *mg. A* 299 horarum] earum *A* 305 gradibus] gradus *AS* 305–306 longitudinis … ignote] *om. per hom. S* 307 eidem] idem *AS* 311 media] dimidia *A* 313 pauciores] paucioris *A* 314–315 occidentalis] orientalis *AS* 316 horarum] eorum *A* ‖ ipse] *om. A* 317 horarum] earum *A* ‖ in] *om. S* ‖ xv] xx *A* 318 partiantur] percipiantur *A* 319 ex xv] xxxv *A* 320 quindecies] qui undecies *A* ‖ lx] 61 *AS* ‖ id est] *om. A*

column for collected years. In no less a fashion, he shall discern, in accordance with what we have taught earlier, how many residual years that are left after subtracting a grouping and [how many] months and days as well as hours and minutes must be used to enter their [respective] tables.

〈Lc5〉 *How to use an eclipse of the Sun and Moon to find the longitude of any place*

If the reader of this art wishes to use an eclipse of the Sun or Moon to find the longitude of a place that is unknown to him, he will investigate by careful reasoning the difference between hours and their parts that mark the beginning or end of a solar or lunar eclipse that takes place both in his own region and in another one, namely, one whose longitude is known. Having found this, he must convert the hours of this difference with their parts into degrees. Having gathered these degrees and committed them to memory, if the region of unknown longitude is to the west of the region of known longitude, he must subtract these from the degrees of the known longitude of the other region, and he shall not doubt that the remainder is the longitude of his own region. But if the region of unknown longitude is to the east of the region of known longitude, one must add the same degrees to the same known longitude and [the result] will be this same thing.

The beginning or end of an eclipse that takes place in both regions also provides an easy way to assess whether the region of unknown longitude is to the east or west of the region of known longitude. For if the number of hours and their parts that one has gathered from the noon or midnight of the day of the eclipse to the beginning or end of the eclipse is greater in the region of known longitude but smaller in the region of unknown longitude, the region of unknown longitude will be to the west of the region of known longitude, and vice versa.

But the parts of the hours, too, are converted into degrees, using the following method. For these parts of hours are either multiplied by 15 and divided by 60, or, if one prefers, one must divide these parts by 4 without a multiplication to turn them, too, into degrees. For an equal hour, seeing as it consists of 15 equal degrees, can be seen to comprise 15 times 60, that is, 900 minutes of the equinoctial circle. If these are divided into 60 equal parts, which they call the 'minutes' of one hour, each of their parts will be equal to one fourth of one degree, which are 15 minutes. For this reason multiply-

xv, erit equalis. Ob hoc igitur, quotiens minuta horarum in xv ducta fuerint, in minuta graduum dissolvuntur, que videlicet si per lx divisa fuerint in gradus integros reducuntur. Amplius, si minuta earum per quatuor diviseris, ipsa quidem in gradus reduces. Integros unum etenim hore minutum xv unius gradus minuta continet. Quotiens igitur quatuor minuta unius hore habueris, totiens te unum gradum habere necesse est. Quater enim xv lx constituunt.

Hac igitur ratione iuxta communem astrologorum sententiam longitudines locorum per eclipsim Solis et Lune inveniuntur. Et ne lectoris animum huius investigationis labor decipiat, tabulam supponimus, in qua videlicet longitudines et latitudines quarundam regionum certa inquisitione posuimus, ut, cum opus fuerit, per ipsas longitudines ad quedam sequentia lector facilius possit accedere.

Nomina regionum et urbium	**Longitudines urbium**		**⟨Latitudines⟩**	
	gradus	**⟨minuta⟩**	**gradus**	**minuta**
Baldac	81		33	
Aracca	73		38	
Ierusalem	55		33	
Tropolis Barba	39		30	
Babilonia	45		30	
Africa	36		35	
Sicilia	35		35	
Pannonia	33		38	
Miscene	35		36	
Roma	35		41	
Pisa	33		45	

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323 xv] que *add. A* ‖ horarum] earum *A* 331 inveniuntur] Sed et si absque eclipsium prenotatione iuxta Toleti doctores id ipsum tractare volueris, ipsam horam et eius partem qua quilibet gradus signiferi seu quelibet stella fixa in duabus regionibus, note scilicet et ignote longitudinis, celum mediaverit observabis ipsamque horarum utriusque regionis differentiam diligenti ratione notabis. Quibus annotatis prout iuxta communem astrologorum sententiam predocuimus cetera omnia pertractentur. *add. A* 336 nomina ... urbium] *mg. A* 336–337 longitudines urbium] *om. A* 338 gradus] *om. A* ‖ minuta] *om. A* 340 Aracca] Aracta *A* 342 Barba] Bacha *A* 346 38] 35 *A* 347 Miscene] Miisene *A* ‖ 35] 32 *A* 349 Pisa] Pisis *A*

ing the minutes of an hour by 15 dissolves them into minutes of a degree. If these are divided by 60, they are evidently reduced to whole degrees. What is more, if you divide the minutes of [an hour] by 4, you will reduce them to degrees. For one minute of an hour comprises in full 15 minutes of one degree. You will therefore necessarily have as many times one degree as you have 4 minutes of an hour, seeing as 4 times 15 make 60.

This is the method, then, by which an eclipse of the Sun and Moon can be used to find the longitudes of places in accordance with what is commonly accepted among astronomers. And to keep the reader's mind from being frustrated by the labour involved in this investigation, we subjoin a table, in which we place the longitudes and latitudes of certain regions [that have been established] by reliable investigation, so that the reader can more easily get from these longitudes to certain others, when it is needed.

Names of regions and cities	**Longitudes of cities**		**Latitudes**	
	degrees	**minutes**	**degrees**	**minutes**
Baghdad	81		33	
ar-Raqqah	73		38	
Jerusalem	55		33	
Tripoli	39		30	
Babylonia	45		30	
Africa	36		35	
Sicily	35		35	
Palermo	33		38	
Messina	35		36	
Rome	35		41	
Pisa	33		45	

(*cont.*)

Nomina regionum et urbium	**Longitudines urbium**		**⟨Latitudines⟩**	
	gradus	**⟨minuta⟩**	**gradus**	**minuta**
Alexandria	45		30	
Almaria	30		36	
Corduba	28		38	
Hispalis	27		38	
Toletum	28	30	40	
Cesar Augusta	29		42	
Bugea	32		34	
Marroca	17		30	
Osca	27		40	
Valencia	29		39	
Denia	28		39	
Anglia	18		52	

⟨Lc6⟩ *De planetarum VII et capitis Draconis Lune locorum medialium inventione*

Planetarum vero VII et capitis Draconis Lune loca medialia ad civitatis Londoniarum meridiem iuxta quam liber iste constituitur hoc modo efficiuntur. Primo quidem sic. Quantum igitur temporis ab huius operis initio per diminutionem annorum MCXLIX ex annis domini completis in tempus presens transierit precedit agnitio. Deinde annorum residuorum post diminutionem vigena sequitur divisio eiusque quod ex ipsis annis reliquum fuerit certa notitia. Tertio siquidem loco per eas vigenas earumque notum reliquum necnon et per numerum mensium et dierum et horarum ac minutorum preteritorum in tempus presens in tabulas mediales patet ingressio eorumque omnium adiunctorum, ut superius disseruimus, certa ac naturalis dispositio.

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356 28] 9 *add. s.l. A* ‖ 38] 35 *A* 357 27] 10 *add. s.l. A* ‖ 38] 35 *A* 358 28] 11 *add. s.l. A* ‖ 30] *om. A* ‖ 40] 30 *S* 359 Cesar Augusta] Augusti Cesar *S* ‖ 29] 12 *add. s.l. A* 360 32] 15 *add. s.l. A* ‖ 34] 30 *A* 361 17] 0 *add. s.l. A* 362 27] 10 *add. s.l. A* 363 29] 12 *add. s.l. A* 364 28] 11 *add. s.l. A* 366–367 De … inventione] *om. A*; *mg. S* 368 planetarum] planete *S*

(*cont.*)

Names of regions and cities	Longitudes of cities		Latitudes	
	degrees	minutes	degrees	minutes
Alexandria	45		30	
Almería	30		36	
Córdoba	28		38	
Seville	27		38	
Toledo	28	30	40	
Zaragoza	29		42	
Béjaïa	32		34	
Morocco	17		30	
Osca	27		40	
Valencia	29		39	
Dénia	28		39	
England	18		52	

⟨Lc6⟩ *On how to find the mean positions of the seven planets and the lunar ascending node*

The mean positions of the seven planets and the lunar ascending node for the meridian of the city of London, according to which this book is arranged, are derived in the following way. The first step, assuredly, is to subtract 1149 from the completed years AD to discern the amount of time that has passed between the beginning of this work and the present. The next is to divide the remaining years by 20 and to note with exactitude what is left of these years. In a third step, one uses this multiple of 20 and the noted remainder as well as the number of months, days, hours, and minutes that have gone by until the present time to determine how to enter the mean[-motion] tables and arrange all their entries in a reliable and natural manner, as we have set

Ad ultimum vero minorum in maiora artificiosa accedit conversio, ut videlicet planetarum VII et capitis Draconis Lune locorum medialium ab Ariete sumpto initio certa habeatur inventio.

Nunc vero que diximus evidentius explicemus. Ex annis igitur domini completis MCXLIX annos diminue quodque superfuerit quantum temporis ab operis initio in tempus presens annuatim transerit ipsum indicabit. Id ipsum ergo per XX divide et quot vigene inde provenerit anni quidem collecti quotquot anni minus XX remanserint anni dicentur residui. Cum collectis igitur annis in lineam annorum collectorum ingrede quodque illis ex signis, gradibus, minutis atque secundis adiunctum fuerit in albiolo, ut predictum est, solerter dispone. Similiter et cum annis residuis in lineas annorum residuorum ingrede eorumque adiunctum sub priori adiuncto naturali dispositione, signa scilicet sub signis, gradus sub gradibus, minuta sub minutis, secunda sub secundis, constitue. Hec enim omnium adiunctorum naturalis est dispositio.

Inde vero cum completis mensibus presentis anni, id est non completi, in menses ingrede eorumque adiunctum sub aliis adiunctis modo superiori dispone. Nec minus et cum diebus completis eiusdem mensis in tabulam dierum ingrede eorumque adiunctum sub prioribus adiunctis ut prius constitue. Similiter etiam cum horis iam completis in earum numerum intrabis quodque illis adiunctum fuerit sub aliis adiunctis ut supra notabis. Cum minutis quoque hore completis in eorum numerum ingrede eorumque adiunctum sub aliis simili ratione dispone.

His igitur omnibus ita dispositis omnia secunda in unum collige eaque per LX divide quodque inde provenerit erunt minuta. Reliquum vero secunda remanent. Similiter omnia minuta simul collige ipsaque per LX divide et quod inde provenerit gradus erunt. Reliquum vero minuta remanent. Inde vero omnes gradus simul adiunge ipsosque per XXX divide. Quod enim inde provenerit signa erunt. Reliquum vero gradus remanent. Demum quoque omnia signa simul collige ipsaque per XII divide. Quod inde provenerit id totum abice. Reliquum vero signa remanent. Hec igitur signa, gradus, minuta, secunda remanentia locum medialem, id est medium cursum, eius planete, cuius videlicet locus in questione ceciderit, certa indagatione ostendent. Ab Ariete ergo sumpto initio signa signis, gradus gradibus, minuta minutis, secunda secundis distribue. Nam ubi numerus omnium defecerit,

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379 VII] 7 *AS* 383 indicabit] iudicabit *S* 386 quodque] quodqui *A* 398 adiunctum] adiunctis *A* 400 simili ratione] similitudo ne *A* 406 remanent] simul *add. A* 407 simul] *om. A*

out above. The final step, however, is the conversion of smaller into larger [units], as prescribed by the art, so that one can accurately find the mean positions of the seven planets and the lunar ascending node as reckoned from the beginning of Aries.

But now we shall explain what we have [already] said in a clearer fashion. Take 1149 years away from the completed years AD and what is left will reveal the time that has passed in terms of years between the beginning of the work and the present. You must accordingly divide this by 20 and the multiple of 20 that results will be called the collected years and the number of years that remain below 20 [will be called] the residual years. With the collected years, you must consequently enter the column for collected years and skilfully arrange on a sheet the corresponding entries according to signs, degrees, minutes, and seconds, as has been said before. Use in the same way the residual years to enter the column for residual years and place its entries below the earlier ones according to their natural arrangement, namely, signs below signs, degrees below degrees, minutes below minutes, seconds below seconds. For this is the natural arrangement of all the entries [in the tables].

But next you must use the completed months of the present year (i.e., the one that is not yet completed) to enter the [table for] months and arrange its entries below the other entries in the same way as above. In no less a fashion, you must also use the completed days of the same month to enter the table for days and place its entries below previous entries, as before. By the same token, you will also use the already completed hours to enter [the column for] their number and write the entries there below the other entries, as above. Also use the completed minutes of the hour to enter their number and arrange their entries below the others according to the same principle.

Having arranged all of this in this manner, you must group all seconds together and divide them by 60 and the result will be in minutes. What is left, however, remains as seconds. In the same way you must group together all the minutes and divide them by 60 and the result will be in degrees. What is left, however, remains as minutes. But next you must add together all the degrees and divide them by 30. For the result will be in signs. What is left, however, remains as degrees. Last, you must group together all the signs and divide them by 12. What results from this you must throw out whole. What is left, however, remains as signs. These remaining signs, degrees, minutes, [and] seconds will consequently show as a matter of reliable investigation the mean position (i.e., the mean course) of this planet, namely, the one whose position has been asked for. You must accordingly allot signs to signs, degrees to degrees, minutes to minutes, [and] seconds to seconds, while taking the beginning from Aries. For you will not doubt that [the point] where

ibidem in zodiaco planetam ipsum iuxta eius medialitatem ad Londoniarum meridiem proculdubio esse non dubites.

Quod si iuxta meridiem alterius regionis vel loci cuius videlicet longitudo maior minorve longitudine Londoniarum fuerit medium cursum planetarum invenire intenderis, quantum planeta quilibet in differentia longitudinum, Londoniarum videlicet et eiusdem alterius loci, progreditur, si idem alter locus Londoniis orientalis fuerit, a medio cursu iuxta meridiem Londoniarum abice; si vero occidentalis fuerit, id ipsum eidem adice; quodque post augmentum vel diminutionem residuum fuerit medium cursum cuiuslibet planete iuxta eundem alterum locum indicabit.

⟨Lc7⟩ *De medio cursu planetarum inveniendo iuxta tempus quodlibet ante huius libri initium*

Quod si medium cursum planetarum iuxta aliquod tempus ante initium preteritum velis colligere, annos quidem domini ab eodem tempore ad annum presentem in quo fueris completos etiam cum ipso anno presente imperfecto ab annis domini usque in eundem annum incompletum perfectis diminue quotquotque superfuerint erunt anni domini ante idem tempus preteritum completi. Quos videlicet cum ex annis domini MCXLIX subtraxeris, annos qui ab ipso tempore preterito usque in huius libri principium transierint optinebis. Hos igitur annos per XX quotiens poteris divide. Nam quot vigenas habueris totiens motus eiusdem planete in annis XX a radice divisim cum eius residuis auferendum erit, ut videlicet annorum collectorum iuxta quod prefatum tempus preteritum patescat introitus. Quod si anni ab ipso anno preterito in initium libri minus XX fuerint, ipsos quidem a XX subtrahe quotque remanserint anni erunt residui per quos videlicet in tabula annorum residuorum eius planete, ut in sequentibus dicetur, fiet introitus. Per menses quoque et dies et horas et momenta preterita anni imperfecti ultimoque anno completo preteriti temporis proximi motus mensualis et diurnus, horarius quoque et momentaneus in suis tabulis colligendus est.

Et ne erroris nebula animum lectoris possit obtegere hoc exemplum licet subicere: anno igitur domini MCLXX annos domini completos ab anno cuiusdam solaris eclipsis XXXII reperio. Quos videlicet, si cum anno imperfecto, qui scilicet XXX tertius est annus, ab annis domini iuxta eundem annum completis, qui MCLXIX sunt anni, subtraxero, M quidem XXXVI anni

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414 meridiem] medietatem *A* 417 invenire intenderis] intenderis invenire *A* ‖ planeta] plura *AS* 420 id] ad *S* 421 residuum] reliquum *A* 422 indicabit] iudicabit *S* 423–424 De … initium] *mg. A* 427 etiam] et *S* ‖ presente] presentem *A* 436 a XX] LXX *A* 440–441 mensualis et diurnus] mensera vel et diurnius *A* 442 animum] animi inde *A*

the number of all of them finishes [marks] the [position] of the planet in the zodiac according to its mean [course] for the meridian of London.

But if you aim to find the mean course of the planets according to the meridian of another region or place, namely, one whose longitude is greater or smaller than that of London, you must subtract from the mean course according to the meridian of London the amount by which a given planet moves over the difference between the longitudes (i.e., of London and that other place) in case the other place is east of London; but if it is to the west, you must add to it the same amount; and what is left after the addition or subtraction will show the mean course of a given planet according to this other location.

⟨Lc7⟩ *On how to find the mean course of the planets according to any date before the beginning of this book*

But if you wish to derive the mean course of the planets according to some date that precedes the beginning, you must take the years AD that have been completed between this date and the present year in which you are and subtract them, together with the present unfinished year, from the years AD that have been completed up to the same incomplete year, and however many are left will be the years AD that have been completed before the past date in question. When you subtract these [years] from 1149 years AD, you will evidently obtain the years that have passed between this past date and the beginning of this book. You must consequently divide these years by 20 as many times as you can. For the resulting multiple of 20 shows you how often you must subtract the motion of the relevant planet in 20 years from the root while leaving the residual [years] aside, so as to reveal the collected-year entry that corresponds to the aforementioned past date. But if there are fewer than 20 years between that past year and the beginning of the book, you must subtract them from 20 and the number that remains will be the residual years that will be used to enter the table for residual years of this planet, as will be said in what follows. And with the final year having been completed, one must also use the months, days, hours, and minutes that have passed in the unfinished year to gather, from the respective tables, the motion per month, day, hour, and moment of the immediately preceding period.

And to keep the fog of error from engulfing the reader's mind, it will be permitted to subjoin the following example: in the year AD 1170 I find that 32 years AD have been completed since the year of a certain solar eclipse. If I take these together with the incomplete year, which is the 33rd year, and subtract them from the years AD that are complete according to the same

completi ante annum prefate eclipsis inveniuntur. Anno igitur domini MCXXXVII, mense Maio, die eius vicesimo primo, feria sexta, hora diei octava fere transacta solaris eclipsis fere medialis apparuit. Si igitur annos MCXXXVI completos ex annis domini MCXLIX diminuero, annos tresdecim residuos procul dubio reperio. Quos videlicet, quoniam per XX dividere nequeo, ipsos quidem a XX subtraho annosque VII residuos optineo. Ut igitur in tabula annorum collectorum cuiuslibet planete fiat introitus, motum eiusdem planete in annis XX, qui scilicet in directo ultime linee tabule annorum residuorum inscribitur, radici subtraho locumque planete eiusdem in signis et gradibus, minutis quoque ac secundis in fine anni vicesimi ante libri initium iuxta planete medialem cursum reperio. Inde vero per VII annos residuos in tabulam residuorum annorum introeo eiusque adiunctum sub signis et gradibus, minutis et secundis per annos collectos prius signatis constituo. Itidem per menses et dies et horas et momenta preterita iuxta quod predocuimus in eorum tabulas fiat introitus eorumque adiuncta sub aliis adiunctis, ut superius disseruimus, notentur, ut ratione premissa minoribus in maiora redactis medius cursus eiusdem planete ad horam eiusdem eclipsis certissime inveniatur.

Quod si ea que superius dicta sunt facilius exequi volueris, quot anni a prefato tempore preterito in annum presentem fuerint diligenter computa. Ex quibus omnibus etiam cum ipso anno imperfecto annos ab huius operis initio completos diminue et per eorum reliquum iuxta quod supra dictum est medium cursum planetarum inquire.

⟨Lc8⟩ *De absidum planetarum VII inventione*

Astrologorum vero de absidibus planetarum, id est de eorum sublimationibus, duplex reperitur sententia. Quidam namque eorum eas cum suis circulis immobiles perhibent et a locis quibus create sunt numquam posse removeri. Alii vero illas cum suis circulis a primis earum locis removeri motumque stellarum fixarum, ab occasu scilicet in ortum itemque ab ortu in occasum neque celerius neque tardius, sed consimili semper uno eodemque temporis spatio, eas necessario probant imitari. Habent enim stelle fixe omnes proprium ac naturalem motum per quem videlicet contra mundum nitentes in XXIIII milibus annorum equa semper ac uniformi agitatione a puncto a quo progredi incipiunt revertuntur. Omnes enim tamquam immobiles in

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457 annos] *om. A* 457–458 tabulam] tabula *A* 458 introeo] introio *A*; introiero *S* 460 et dies] *om. A* 470 De … inventione] De altitudine planetarum VII inventione *mg. A* 471 id est] *om. S* 471–472 sublimationibus] sublimaterionibus *A* 472 Quidam] Quidem *A* ‖ eorum] earum *A* 474 earum] eorum *A* 477 imitari] mutari *S* ‖ enim] etiam *S*

year, which are 1169 years, what is found are 1136 years that are completed before the year of the aforementioned eclipse. It was in AD 1137, then, in the month of May, on its 21st day, on the sixth day of the week, when roughly the eighth hour had passed, that a solar eclipse that was about half[-total] appeared. If I accordingly subtract 1136 completed years from 1149 years AD, I doubtlessly find 13 residual years. Since I am not able to divide these by 20, I subtract them from 20 and obtain 7 residual years. In order to enter the table for collected years of a given planet, I subtract from the root the motion of this planet in 20 years, which is written next to the final line in the table for residual years, and I find the position of the same planet in signs, degrees, minutes, and seconds according to the planet's mean course at the end of the 20th year before the beginning of the book. But next I take 7 residual years to enter the table for residual years and place its entry below the signs, degrees, minutes, and seconds of the collected years that have been noted earlier. In the same manner, the months, days, and moments that have gone by are used, in accordance with what we have taught earlier, to enter the corresponding tables, and their entries must be noted below the other entries, as we have discussed above, so that, once smaller [units] have been reduced to larger ones according to the aforementioned method, the mean course of this planet at the hour of this eclipse is found with the greatest exactitude.

But if you wish to arrive at what has been said above in an easier manner, you must carefully calculate the number of years between the aforementioned past date and the present year. From this whole number together with the incomplete year you must subtract the years that have been completed since the beginning of the work and use the remainder to examine the mean course of the planets in accordance with what has been said above.

〈Lc8〉 *On how to find the apogees of the seven planets*

Among the astronomers one can find two different opinions with regard to the apogees of the planets, that is, with regard to their highest points. For certain among them hold that they remain immobile in their circles and that they can never withdraw from the positions at which they were created. Others, by contrast, prove that they together with their circles necessarily withdraw from their initial positions and imitate the motion of the fixed stars, namely, [by going] from west to east, and likewise from east to west, neither faster nor slower, but always in the same way in one and the same time span. For all the fixed stars have a proper and natural motion by which they, as they advance against [direction of] the world, always return after 24,000 years with an equal and uniform motion to their starting point. For they all are arranged as if immobile in one spherical ring dance and [hence]

uno choro orbiculari constitute consimilis velocitatis volutatione circumferuntur. Sed ob hoc fixe dicuntur quoniam ad earum de signo ad signum promotionem visu sensibilem nullius etas se potuit extendere, cum in duobus milibus annorum signum unum necesse sit eas transmeare.

Hunc igitur motum absides planetarum cum eorum circulis imitantur, quem videlicet nec festinando preterire neque recedendo possunt deserere. Nam quemadmodum stelle fixe in LXVI annis et octo mensibus solaribus unam signi partem, id est gradum unum, perficiunt, ita et absides planetarum consimili temporis spatio consimilem signi particulam transcurrunt. Quo fit ut si quis sciat quantum celestis spere ab uno tempore ad aliud stelle fixe transierint, hoc ipsum etiam ipsius spere absides planetarum in consimili tempore transiisse non dubitet. Unde necessario per stellas fixas remotio absidum stellarumque fixarum remotio per absides dinoscitur planetarum. Et quoniam absque certitudine absidum certa planetarum fieri nequit equatio, tabula subicitur per quam videlicet certitudo absidum habeatur.

Hec igitur tabula iuxta huius libri principium per annos domini collectos et residuos, menses quoque et dies et horas in tempus futurum contexitur, ut videlicet quemadmodum medialium locorum planetarum ex eorum tabulis elicitur, ita et ex ista non dissimiliter certitudo absidum eliciatur. Primo igitur in hanc tabulam per annos domini collectos et residuos, menses quoque preteritos et dies et horas preteritas iuxta quod supra docuimus fiat ingressio. Et omnium adiunctorum naturalis sequatur dispositio, minorum quoque in maiora conversiva collectio. Necnon et collectionis tum sexagena, tum trigena, tum vero duodena sequatur divisio, ut quicquid ex divisione provenerit inventa absidum fiat certitudo.

Quoniam igitur omnium absidum in eodem temporis spatio consimilis reperitur progressio, una ex omnibus, id est absis Solis, in hac tabula disponitur, ut qua zodiaci circuli partem vel partes annuali motu vel mensuali, diurno quoque vel horario ipsa transierit, tempore eodem eandem partem vel partes zodiaci circuli aliorum planetarum absides transcurrere lector non dubitet. Quantum igitur earum progressiones in aliquo tempore per hanc tabulam computando colligitur illis omnibus iuxta huius libri initium prius inventis addendum erit. Eius namque illis adiectio absidum erit certitudo.

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482 sed] et *add. A* ‖ earum] eorum *A* 484 eas] eos *A* 485 absides] absit ex *A* 488–489 planetarum] in *add. A* 493 stellarumque] stellarum *S* 495 subicitur per quam] subditur postquam *A* 498 videlicet] et *add. S* ‖ ex] et *A* 506 quoniam] [S_2 ‖ igitur] *om.* S_2 507 hac tabula] hanc tabulam *AS* 507–508 disponitur] disponuntur *A* 509 tempore eodem] eodem tempore *A* 510 aliorum] aliarum *A* 512 huius] *om.* S_2 ‖ initium] qui est de eo(?) factum ad meridiem Londoniarum *add.* S_2

are carried around by a revolution of the same speed. The reason, however, they are called 'fixed' is that no one has grown old enough to visually perceive their advance from one sign to another, seeing as it necessarily takes them 2000 years to go across a single sign.

This is the motion that the apogees of the planets imitate together with their circles, and which they can neither anticipate by hurrying ahead nor abandon by going backwards. For just as the fixed stars complete one part of a sign, which is one degree, in 66 years and 8 months, so the apogees of the planets go across the same part of a sign in the same span of time. Consequently, if someone knows the amount of the celestial sphere that the fixed stars cross between one point in time and another, he must not doubt that the apogees of the planets have crossed the same amount of the celestial sphere during the same time. It follows necessarily that the motion of the apogees can be inferred from the motion of the fixed stars and the [motion] of the fixed stars from the [motion] of the apogees. And since it is not possible to compute reliably the equation of the planets without exact knowledge of the apogees, a table is placed below that makes it possible to have exact knowledge of the apogees.

This table is constructed [by counting] forward from the beginning of this book the collected and residual years AD as well months, days, and hours, so that just as one derives the mean positions of the planets from their respective tables, one can in the same way derive from this one exact knowledge of the apogees. The first step is to enter this table with the collected and residual years AD as well as the months, days, and hours that have gone by in accordance with what we have taught above. And [what follows] is the natural arrangement of all their entries as well as the conversion of smaller [units] into larger ones; and also the division of what has been gathered, now by 60, now by 30, now by 12, so that what comes out of the division leads to exact knowledge of the apogees.

Since the forward motion of all apogees is found to cover the same space in the same time, a single one among them all, namely, the apogee of the Sun, is arranged in this table, so that the reader does not doubt that the part or parts of the zodiacal circle that it crosses during an annual or monthly as well as daily or hourly motion is the same as the part or parts of the zodiacal circle that the apogees of the other planets cross in the same period of time. The amount of forward motion that is derived by computation from this table for a given span of time one will accordingly have to be added to all of their previously determined [positions] according to the beginning of this book. For

Cum igitur per hanc tabulam Solis absidem iuxta presens tempus invenietis, que absidem in capite huius tabule inscribitur ei subtrahe et quod remanserit absidibus aliorum planetarum iuxta libri initium inventis adice et ita eorum certitudinem te reperisse cognosce. Non dissimili quoque ratione, si quis loca stellarum fixarum in initio huius libri agnoverit, quantum contra mundum in tempus futurum ipse processerint facillime per hanc tabulam reperire poterit. Unde et eorum iuxta Albatem annullatur opinio qui absides planetarum immobiles esse contendunt.

Tabula absidis Solis ut per eam absides aliorum planetarum iuxta presens tempus inveniantur

Absis Solis in annis domini collectis

anni collecti	**signa**	**gradus**	**minuta**	**secunda**
radix	2	26	21	18
29	2	26	39	18
49	2	26	57	18
69	2	26	15	18
89	2	27	33	18
109	2	27	51	18
129	2	27	9	18
149	2	28	27	18
169	2	28	45	18
189	2	29	3	18
209	2	29	21	18
229	2	29	39	18
249	2	29	57	18
269	3	0	15	18
289	3	0	33	18
309	3	0	51	18
329	3	1	9	18
349	3	1	27	18

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514 per] *om.* S_2 516 aliorum] aliarum *A* ‖ planetarum] planete S_2 ‖ initium] *om.* SS_2 517 non] nunc S_2 518 huius] dicti S_2 ‖ agnoverit] cognoverit S_2 519 processerint] processerit SS_2 520–521 Unde … contendunt] *om.* S_2 522–523 tabula … inveniantur] *om.* *A* 523 tempus] *om.* S_2 524 absis … collectis] absidis solis in annis in annis collectis *A*

adding this leads to exact knowledge of the apogees. Once you have found from this table the apogee of the Sun for the present time, you must consequently subtract from it the apogee that is written at the head of this table and add the remainder to the apogees of the other planets according to the beginning of the book. And this way you shall know that you have obtained exact knowledge of [their position]. By the same principle, if someone has discerned the positions of the fixed stars at the beginning of this book, he will with the help of this table be able to find with great ease the amount of their future progress against [the direction of] the world. The opinion of those who claim the apogees of the planets to be immobile is thus destroyed in accordance with al-Battānī.

Table of the solar apogee, so one can use it to find the apogees of the other planets according to the present time

The solar apogee in collected years AD

collected years	**signs**	**degrees**	**minutes**	**seconds**
root	2	26	21	18
29	2	26	39	18
49	2	26	57	18
69	2	26	15	18
89	2	27	33	18
109	2	27	51	18
129	2	27	9	18
149	2	28	27	18
169	2	28	45	18
189	2	29	3	18
209	2	29	21	18
229	2	29	39	18
249	2	29	57	18
269	3	0	15	18
289	3	0	33	18
309	3	0	51	18
329	3	1	9	18
349	3	1	27	18

(*cont.*)

Absis Solis in annis domini collectis

anni collecti	signa	gradus	minuta	secunda
369	3	1	45	18
389	3	2	3	18
409	3	2	21	18
429	3	2	39	18
449	3	2	57	18
469	3	3	15	18
489	3	3	33	18
509	3	3	51	18
529	3	3	9	18

Absis Solis in annis residuis

anni residui	minuta	secunda
1	0	54
2	1	48
3	2	42
4	3	36
5	4	30
6	5	24
7	6	18
8	7	12
9	8	6
10	9	0
11	10	54
12	10	48
13	11	42
14	12	36

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556 absis … residuis] *om.* S_2

(*cont.*)

The solar apogee in collected years AD

collected years	signs	degrees	minutes	seconds
369	3	1	45	18
389	3	2	3	18
409	3	2	21	18
429	3	2	39	18
449	3	2	57	18
469	3	3	15	18
489	3	3	33	18
509	3	3	51	18
529	3	3	9	18

The solar apogee in residual years

residual years	minutes	seconds
1	0	54
2	1	48
3	2	42
4	3	36
5	4	30
6	5	24
7	6	18
8	7	12
9	8	6
10	9	0
11	10	54
12	10	48
13	11	42
14	12	36

(*cont.*)

Absis Solis in annis residuis

anni residui	minuta	secunda
15	13	30
16	14	24
17	15	18
18	16	12
19	17	6
20	18	0

Absis Solis in mensibus

menses solares	secunda	tertia
Martius	4	30
Aprilis	9	0
Maius	13	30
Iunius	18	0
Iulius	22	30
Augustus	27	0
September	31	30
October	36	0
November	40	30
December	45	0
Ianuarius	49	30
Februarius	54	0

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581 absis ... mensibus] *om.* S_2 582 tertia] *om.* SS_2

(*cont.*)

The solar apogee in residual years		
residual years	**minutes**	**seconds**
15	13	30
16	14	24
17	15	18
18	16	12
19	17	6
20	18	0

The solar apogee in months		
solar months	**seconds**	**thirds**
March	4	30
April	9	0
May	13	30
June	18	0
July	22	30
August	27	0
September	31	30
October	36	0
November	40	30
December	45	0
January	49	30
February	54	0

Absis Solis in diebus

numerus dierum	secunda	tertia
1	0	9
2	0	18
3	0	27
4	0	36
5	0	45
6	0	54
7	1	3
8	1	12
9	1	21
10	1	30
11	1	39
12	1	48
13	1	57
14	2	6
15	2	15
16	2	24
17	2	33
18	2	42
19	2	51
20	3	0
21	3	9
22	3	18
23	3	27
24	3	36
25	3	45
26	3	54
27	4	3
28	4	12
29	4	21
30	4	30

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595 absis … diebus] *om.* S_2 596 secunda] secundi *S*

The solar apogee in days

number of days	seconds	thirds
1	0	9
2	0	18
3	0	27
4	0	36
5	0	45
6	0	54
7	1	3
8	1	12
9	1	21
10	1	30
11	1	39
12	1	48
13	1	57
14	2	6
15	2	15
16	2	24
17	2	33
18	2	42
19	2	51
20	3	0
21	3	9
22	3	18
23	3	27
24	3	36
25	3	45
26	3	54
27	4	3
28	4	12
29	4	21
30	4	30

Absis Solis in horis

numerus horarum	tertia	quarta	quinta
1	0	22	30
2	0	45	0
3	1	7	30
4	0	30	0
5	0	52	30
6	2	15	0
7	0	37	30
8	3	0	0
9	0	22	30
10	0	45	0
11	4	7	30
12	0	30	0
13	0	52	30
14	5	15	0
15	0	37	30
16	6	0	0
17	0	22	30
18	0	45	0
19	7	7	30
20	0	30	0
21	0	52	30
22	8	15	0
23	0	37	30
24	9	0	0

⟨Lc9⟩ *De loco Solis inveniendo*

Primo igitur medius cursus Solis investigandus est. Secundo absis Solis iuxta tempus presens inventa a medio cursu Solis auferenda reliquumque argumentum Solis dicendum. Tertio cum ipso argumento per lineas numeri in coequationem Solis intrandum eiusque adiunctum notandum. Quarto utrum argumentum introducens maius minusve sex signis extiterit consi-

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627 absis … horis] *om.* S_2 653 De … inveniendo] *om. L* 655 tempus presens] presens tempus *L* 658 sex] vi *L*

The solar apogee in hours

the number of hours	thirds	fourths	fifths
1	0	22	30
2	0	45	0
3	1	7	30
4	0	30	0
5	0	52	30
6	2	15	0
7	0	37	30
8	3	0	0
9	0	22	30
10	0	45	0
11	4	7	30
12	0	30	0
13	0	52	30
14	5	15	0
15	0	37	30
16	6	0	0
17	0	22	30
18	0	45	0
19	7	7	30
20	0	30	0
21	0	52	30
22	8	15	0
23	0	37	30
24	9	0	0

⟨Lc9⟩ *On how to find the position of the Sun*

First one must investigate the mean course of the Sun. Second, one must subtract the solar apogee at the present date from the mean course of the Sun and call the remainder the ‘argument’ of the Sun. Third, one must use this argument to enter the equation of the Sun via the column of numbers and take note of the corresponding entry. Fourth, one must consider whether the argument [used] to enter [the equation] is greater or less than six signs. For

derandum. Si enim maius fuerit, eius adiunctum medio cursui addendum; si vero minus, idem eidem auferendum erit. Ad quemcumque ergo numerum, signorum scilicet et graduum, post adiuncti augmentum seu diminutionem medius cursus pervenerit, ipse quidem ab Ariete sumpto initio locum Solis certissimum in signis tantum et gradibus indicabit.

Quod si cum signis et gradibus locum Solis etiam in minutis scire volueris, cum eius argumento uno gradu eius gradibus addito per lineas numeri recte intrandum eiusque adiunctum notandum. Quodque adiunctorum maius extiterit intuendum atque minus a maiori auferendum eorumque reliquum in minuta argumenti ducendum quodque ex ductu pervenerit per LX dividendum erit. Si igitur adiunctum secundum maius primo extiterit, id quod ex sexagena divisione provenerit adiuncto primo addendum erit; si vero minus, idem eidem auferendum erit; sicque adiunctum primum coequatum esse dicetur. Hoc igitur adiunctum medio cursui iuxta argumenti rationem addendum vel minuendum erit, ut locus Solis certissimus in signis et gradibus et minutis habeatur.

⟨Lc10⟩ *De Solis declinatione*

Cum autem Solis declinationem, id est quantum Sol a regione equinoctiali in aquilonem vel austrum discesserit, scire volueris, cum loco quidem ipsius prius coequato per lineas numeri in tabulam eius declinationis intrabitur eiusque adiunctum notabitur. Ipsum enim adiunctum quesitum ostendet. Pars vero declinationis, ut pars latitudinis Lune et quinque planetarum per eorum argumenta elicitur, ita per locum Solis coequatum elicienda erit.

⟨Lc11⟩ *De loco Lune inveniendo*

Lune vero locus hac ratione colligitur. In primis igitur medium cursum Solis et medium cursum Lune necnon et eius argumentum, ut supradictum est, elice. Medium cursum Solis a medio Lune diminue eorumque reliquum in se duplicatum duplex interstitium constitue. Cum hoc namque interstitio per lineas numeri in centri coequationem et minuta proportionalia simul intrabitur eiusque ex utroque adiunctum divisim notabitur. Si igitur duplex interstitium minus VI signis extiterit, centri coequationem Lune argumento

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659 enim] vero *A* 660 numerum] *add.* et *A* 661 augmentum] argumentum *A* 662 ab … initio] sumpto ab Ariete *A* 664 si cum] sicud *A* ‖ minutis] si *A* 665 eius] eiusdem *A* 670 provenerit] provenit *AS* 671 erit] *om. S* 675 de … declinatione] *mg. A* 676 equinoctiali] equinoctialium *S* 682 De … inveniendo] *om. A; mg. S* 683 vero] *om. AL* 684 et] in *S* ‖ cursum] *om. AL* 685 diminue] dimpane *A*; medium … diminue] *om. S* 686 hoc namque] vero namque hoc *S* 687 coequationem] coequationi *A*; coequatione *S*

if it is greater, the corresponding entry must be added to the mean course. But if it is less, it must be subtracted from it. Whatever number of signs and degrees the mean course has reached after adding or subtracting the entry, the same will evidently reveal the exact position of the Sun according to signs and degrees, with the beginning taken from Aries.

But if, along with the signs and degrees, you also wish to know the position of the Sun in minutes, one must add one degree to its argument and seek the appropriate [line] in the column of numbers and take note of the corresponding entry. And one will have to consider which of the entries is greater and subtract the greater from the smaller and multiply what is left by the minutes of the argument and divide the product by 60. If the second entry is greater than the first, one must take the result after dividing by 60 and add it to the first entry; but if it is smaller, it must be subtracted from it; and thus one will say that the first entry has been equated. This entry will consequently have to be added to or subtracted from the mean course according to the principle of [computing] the argument so as to obtain the exact position of the Sun according to signs, degrees, and minutes.

⟨Lc10⟩ *On the solar declination*

In case, however, you wish to know the solar declination, which is the amount by which the Sun has departed from the equinoctial region towards the north or the south, one will use its previously equated position to enter the column of numbers in the table of its declination and take note of the corresponding entry. For this entry will show what has been asked for. But the amount of the declination will have to be derived via the equated position of the Sun in the same way as the latitude of the Moon and of the five planets is derived via their respective arguments.

⟨Lc11⟩ *On how to find the position of the Moon*

The position of the Moon, however, is gathered in the following way. First you must derive the mean course of the Sun and the mean course of the Moon as well as its argument, as has been stated above. Subtract the mean course of the Sun from the mean [course] of the Moon and form the double elongation by doubling the remainder. For this elongation will be used to enter both the equation of centre and the minutes of proportion via the column of numbers and one will take separate note of each of the corresponding entries. If the double elongation is less than 6 signs, you must add the equation of centre to the lunar argument; but if it is greater, you must

adice; si vero maius, eandem eidem subtrahe; sicque argumentum Lune coequatum agnosce. Cum hoc itaque argumento per lineas numeri in equationem diversitatis diametri circuli brevis necnon et in equationem argumenti simul intrandum eiusque ex utroque adiunctum divisim notandum.

Deinde quotacumque pars numeri sexageni minuta proportionalia prius servata fuerint, totam partem equationis diversitatis diametri secernito ipsamque partem argumenti equationi adicito reliquumque prefate equationis totum abicito. Ut si, verbi gratia, minuta proportionalia xxx extiterint, quoniam xxx numeri sexageni sunt medietas, medietatem prefate equationis argumenti equationi adicito, aut, si mavis, totam equationem diversitatis diametri in minuta proportionalia ducito summamque per lx dividito quodque ex divisione provenerit argumenti coequationi, ut supra, adicito, ut sic argumenti Lune coequata fiat coequatio. Si igitur argumentum Lune coequatum maius vi signis extiterit, hanc equationem Lune medio cursui adicito; si vero minus, eandem eidem subtrahito, ut videlicet ab Ariete sumpto initio loci Lune in signis, gradibus et minutis certa habeatur inventio.

⟨Lc12⟩ *De loco capitis Draconis inveniendo*

Locus quidem Draconis capitis hac ratione inveniendus est. Primo igitur eius medium cursum elice ipsumque a signis xii subtrahe quodque residuum fuerit ab Ariete computando eius locum agnosce. Caude vero locus loco capitis per diametrum semper opponitur.

⟨Lc13⟩ *De latitudine Lune invenienda*

Locus itaque capitis Draconis a loco Lune auferatur, vel medius cursus capitis Draconis loco Lune adiciatur. Ex unius namque diminutione alteriusve additione signorum, graduum ceterarumque minutiarum idem numerus proveniet. Quod igitur inde provenerit argumentum latitudinis dicendum erit. Cum ipso itaque argumento per lineas numeri in Lune latitudinem intrandum eiusque adiunctum notandum. Quodcumque eius adiunctum fuerit ipsum quidem Lune latitudinem indicabit. Hinc vero, si latitudinis

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690 vero] *om. AL* ‖ eandem eidem] quidem *A*; *om. L* 690–691 coequatum] equatum *AL* 691 itaque] igitur *L* 694 sexageni] lx *AL* 697 ut … gratia] verbi gratia ut si *A* 698 numeri sexageni] numeri sexagenarii *L*; sexageni numeri *S* 699 aut … mavis] *om. A* ‖ totam] totamque *A* 700 summamque] summam *L* 700–701 quodque] quod *S* 702 coequatio] equatio *AL* 704 vero] *om. AL* ‖ eandem eidem] *om. AL* 705 signis] et *add. A* 706 De … inveniendo] *om. L; mg. S* 707 quidem] *om. L* ‖ Draconis capitis] capitis Draconis *L* 707–708 igitur … medium] medium eius *L* 708 signis xii] xii signis *L* ‖ quodque] quod et *S* 711 De … invenienda] *mg. A*; *om. L*; *mg. S* 712 itaque] *om. L* 714 signorum] et *add. A* 715 proveniet] provenit *S* ‖ igitur] *om. L* 716 in] inter *A*; et *S*

subtract it from it; and in this way you shall discern the equated lunar argument. This argument must consequently be used to enter both the equation of the difference of the diameter of the small circle and the equation of the argument via the column of numbers and one must take a separate note of the corresponding entries.

Next, you must take the part of the equation of the difference of the diameter of the small circle that corresponds to the part of 60 that [is represented] by the minutes of proportion that have been kept previously and add this part to the equation of the argument and throw away the rest of the aforementioned equation. If, for example, there are 30 minutes of proportion, you must add half of the aforementioned equation to the equation of the argument, seeing as 30 are one-half of 60; or, if you prefer, you must multiply the whole equation of the difference of the diameter by the minutes of proportion and divide the product by 60 and add what comes out of the division to the equation of the argument, as before, so as to 'equate' the lunar equation of the argument. But if the equated lunar argument is greater than 6 signs, you must add this equation to the mean motion of the Moon; but if it is less, you must subtract it from it so as to find with exactitude the position of the Moon according to signs, degrees, and minutes, with the beginning taken from Aries.

⟨Lc12⟩ *On how to find the position of the* [*lunar*] *ascending node*

The position of the [lunar] ascending node must be found in the following way. First you must derive its mean course and subtract it from 12 signs and what is left you must interpret as its position reckoned from Aries. The position of the descending node, however, is always diametrically opposite to the position of the ascending node.

⟨Lc13⟩ *On how to find the latitude of the Moon*

One must either subtract the position of the ascending node from the position of the Moon or add the mean course of the ascending node to the position of the Moon. For subtracting one or adding the other will result in the same number of signs, degrees, and the remaining fractions. What results from this will have to be called the argument of latitude. With this argument one must consequently enter the lunar latitude via the column of numbers and take note of the corresponding entry. And whatever this entry may be will reveal the latitude of the Moon. But if you subsequently desire

ipsius ascensum descensumve etiam et si ipsam partem in qua fuerit nosse desideras, ad signa argumenti latitudinis redeundum erit. *Si* enim ipsa *infra tria prima* signa fuerint, latitudo quidem aquilonalis erit *et proclivis*. *Si* vero *infra secunda tria* fuerint, latitudo quidem aquilonalis, *sed declivis*. *Si* autem *infra tertia tria* fuerint, latitudo quidem *australis et declivis*. Quod *si infra* quarta *tria* fuerint, latitudo quidem australis, *sed proclivis*.

⟨Lc14⟩ ***De coniunctione Solis et Lune per compotum invenienda***

Querenti coniunctionem seu oppositionem Solis et Lune, ne id quod iuxta quosdam intricati sermonis prolixa gravitate negligitur neglectumque velut incerti operis tediosa iteratione relinquitur videatur inscibile, ad eius rei doctrinam quodam brevitatis compendio clarius enodandam veri sermonis interpretationem attingamur.

Loca igitur Solis et Lune ad meridiem diei qua luna xxviii^{a} vel xxix^{a} iuxta compotum ecclesiasticum fuerit certa coequandi ratione invenienda sunt. Quibus inventis, si in signis et gradibus et minutis eorum locus unus idemque extiterit, locum quidem et tempus eorum coniunctionis ad eiusdem diei meridiem optinebis. Quod si non fuerit, quis eorum alterum precesserit observabis eorumque interstitium diligenter notabis et notatum per xii dividendo segregabis eiusque partem duodecimam non minus captabis. Quod cum feceris, ipsam partem duodecimam interstitio aggregabis idque totum 'interstitium maius' nominabis. Si igitur Sol Lunam precesserit, ipsum quidem maius interstitium loco Lune predictaque pars duodecima loco Solis addenda erunt. Quod si Luna Solem precesserit, eadem ab eisdem modo superiori detrahenda erunt. Quibus executis, si in signis et gradibus et minutis eorum loca convenerint, locum quidem, sed nondum tempus coniunctionis eorum, recte signasti. Si vero aliter acciderit, omnia quidem interanda donec sic accidat esse non dubites.

Cum igitur locum coniunctionis recte signaveris tempusque eius definitum nondum agnoveris, si igitur tempus coniunctionis definitum, id est

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719 etiam et] et etiam *L* ‖ qua] quo *A*; *S* 721 tria prima] priora tria *S* ‖ fuerint] fuerit *L* 722 secunda tria] tria secunda *L* ‖ fuerint] fuerit *L* 723 tertia tria] tria tertia *L* ‖ fuerint] fuerit *L* ‖ quod] *om. L* 724 fuerint] fuerit *L* ‖ quidem] *om. L* 725 De … invenienda] *mg. S*; De coniunctione Solis et Lune *L* 726 quod] *s.l. L* 727 intricati] intricata *A* ‖ negligitur] *om. A* 728 incerti] menti *A* 730 interpretationem] interpretatione *LS* ‖ attingamur] ascingimur *L*; astingamur *S* 736 et notatum] notatumque *L* 741 erunt] erit *A* sunt *L* 744 signasti] *add.* igitur locum coniunctionis *A* 746–747 definitum] diffinitum *S* 747 igitur] *om. L*

720–724 si … proclivis] *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 15 (ed. Suter 1914: 13). 726 querenti … lune] *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 31 (ed. Suter 1914: 23; *M*, fol. 41va).

to know the ascent or descent of this latitude and the part in which it is, one will have to return to the signs of the argument of latitude. For if it is within the first three signs, the latitude will be northern and ascending. If, by contrast, it is within the second three signs, the latitude will be northern, but descending. But if it is within the third three signs, the latitude will be southern and descending. But if it is within the fourth three signs, the latitude will be southern, but ascending.

⟨Lc14⟩ *On how to find the conjunction of the Sun and Moon by means of the computus*

For him who seeks the conjunction or opposition of the Sun and Moon, lest this matter appear unknowable, being neglected by some on account of the length and heaviness of a complex presentation and left in neglect as if it were the wearisome repetition of a doubtful operation, we shall provide the translation of a reliable account in order to explicate the doctrine of this matter clearly and succinctly.

[First] one should find, by means of an exact [computation] of the equation, the positions of the Sun and Moon at noon on the day that is the 28th or 29th [of the Moon] according to the ecclesiatical *computus*. Once found, if they are in one and the same place according to signs, degrees, and minutes, you will obtain the position and time of their conjunction at the noon of the day in question. But if this is not the case, you will observe which of the two is ahead of the other and carefully take note of the interval and set [it] aside while dividing it by 12 and also seize its 12th part. Once you have done this, you will add this 12th part to the interval and call the whole sum the 'larger interval'. If the Sun is ahead of the Moon, this larger interval must be added to the position of the Moon and the aforementioned 12th part [must be added] to the position of the Sun. But if the Moon is ahead of the Sun, these will have to be subtracted from them in the manner [described] above. Having followed through with this, if their positions coincide according to signs, degrees, and minutes, you have certainly found the correct position, but not yet the time of their conjunction. But if the outcome is different, you will not doubt that everything must be repeated until it comes out this way.

Once you have correctly designated the position of the conjunction and have not yet discerned its precise time, if you wish [also] to know the pre-

horam et minutum coniunctionis Solis et Lune, nosse desideras, in tabulam subscriptam, que videlicet ad motus horarios Solis et Lune colligendos constituitur, intrandum erit. Quod cum feceris, motu Solis horario a Lune motu horario subtracto reliquum quod fuerit 'superamen' Lune dicendum erit. Si igitur Solis et Lune interstitium prius in secunda redactum per Lune superamen, etiam in secunda redactum, diviseris et quod remanserit in LXª ductum per Lune superamen item secaveris, horas et minuta incunctanter habebis.

Linee numeri		**Motus Solis diversus in horis per ipsius argumentum**		**Motus Lune diversus in horis per ipsius argumentum**	
Gradus	**Gradus**	**Minuta**	**Secunda**	**Minuta**	**Secunda**
0	360	2	23	30	18
6	354	2	23	30	19
12	348	2	23	30	21
18	342	2	23	30	24
24	336	2	23	30	28
30	330	2	24	30	35
36	324	2	24	30	43
42	318	2	24	30	51
48	312	2	25	31	1
54	306	2	25	31	12
60	300	2	25	31	24
66	294	2	26	31	38
72	288	2	26	31	53
78	282	2	27	32	8
84	276	2	27	32	25
90	270	2	28	32	42
96	264	2	28	32	59
102	258	2	29	33	17
108	252	2	29	33	36

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751 superamen Lune] Lune superamen *S* 753 etiam … redactum] *om. S* ‖ diviseris et] diviso *A* 754 superamen] foramen *A* ‖ incunctanter] inevitanter *A* 756–758 diversus … argumentum] *om. L* ‖ diversus … argumentum] *om. L* 761 19] 18 *S* 764 336] 3 *S* ‖ 28] 29 *S* 768 1] 50 *S* 771 66] 60 *S* ‖ 38] 39 *S* 772 288] 283 *S* 774 84] 84 *S* ‖ 25] 24 *S* 775 270] 259 *S* 776 264] 254 *S* ‖ 59] 57 *S*

cise time of the conjunction (i.e., the hour and minute of the conjunction of the Sun and Moon), one will have to enter the table written below, which is constructed for the purpose of gathering the hourly motions of the Sun and Moon. Once you have done this, one must subtract the hourly motion of the Sun from the hourly motion of the Moon and call the remainder the 'excess' of the Moon. If you reduce the interval between the Sun and Moon to seconds and divide it by the excess of the Moon, which has also been reduced to seconds, and multiply the remainder by 60 [and] divide it, too, by the excess of the Moon, you will immediately have obtained the hours and minutes.

Columns of numbers		**The variable motion of the Sun in an hour [derived] from its argument**		**The variable motion of the Moon in an hour [derived] from its argument**	
degrees	**degrees**	**minutes**	**seconds**	**minutes**	**seconds**
0	360	2	23	30	18
6	354	2	23	30	19
12	348	2	23	30	21
18	342	2	23	30	24
24	336	2	23	30	28
30	330	2	24	30	35
36	324	2	24	30	43
42	318	2	24	30	51
48	312	2	25	31	1
54	306	2	25	31	12
60	300	2	25	31	24
66	294	2	26	31	38
72	288	2	26	31	53
78	282	2	27	32	8
84	276	2	27	32	25
90	270	2	28	32	42
96	264	2	28	32	59
102	258	2	29	33	17
108	252	2	29	33	36

(*cont.*)

Linee numeri		**Motus Solis diversus in horis per ipsius argumentum**		**Motus Lune diversus in horis per ipsius argumentum**	
Gradus	**Gradus**	**Minuta**	**Secunda**	**Minuta**	**Secunda**
114	246	2	29	33	55
120	240	2	30	34	14
126	234	2	30	34	32
132	228	2	31	34	49
138	222	2	31	35	4
144	216	2	32	35	18
150	210	2	32	35	31
156	204	2	33	35	43
162	198	2	33	35	52
168	192	2	33	35	58
174	186	2	33	36	2
180	180	2	33	36	4

Introitus autem in tabulam prescriptam est ut signa argumenti cuiusvis eorum, Solis scilicet vel Lune, iam coequati in gradus dissolvas ipsosque gradibus eiusdem argumenti adicias et cum illis omnibus aut etiam cum numero eorum omnium numero propiori atque minori in tabulam eandem introeas, ut horarii motus Solis et Lune in momento coniunctionis vel oppositionis eorum reperire queas. Argumentorum siquidem Solis et Lune coequatio cuiusvis eorum coequationis argumento eiusdem est adiectio.

⟨Lc15⟩ *De oppositione Solis et Lune*

Oppositio siquidem Solis et Lune et loca et tempora non dissimiliter invenienda sunt, hoc etiam previso ut, cum ad illa pertractanda perventum fuerit, quando luna xiii^{a} vel xiiii^{a} extiterit eius locus necnon et locus Solis certa

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791 32] 33 *S* 793 162] 172 *S* 794 168] 178 *S* 795 186] 185 *L* 796 33] 3 *S* 800 eorum] illorum *A* 804 De … Lune] De inventione oppositionis Solis et Lune *L*; *mg. S* 805 siquidem] *om. L* 807 vel xiiii^{a}] *om. A*

(*cont.*)

Columns of numbers		The variable motion of the Sun in an hour [derived] from its argument		The variable motion of the Moon in an hour [derived] from its argument	
degrees	**degrees**	**minutes**	**seconds**	**minutes**	**seconds**
114	246	2	29	33	55
120	240	2	30	34	14
126	234	2	30	34	32
132	228	2	31	34	49
138	222	2	31	35	4
144	216	2	32	35	18
150	210	2	32	35	31
156	204	2	33	35	43
162	198	2	33	35	52
168	192	2	33	35	58
174	186	2	33	36	2
180	180	2	33	36	4

But the way to enter the above-written table is to dissolve into degrees the signs of the argument of either of them (i.e., Sun or Moon) after it has already been equated and add [these degrees] to the degrees of the same argument and use their sum or the next-smallest number to enter the table, so that you are able to find the hourly motions of the Sun and Moon at the moment of their conjunction or opposition. The equation of the arguments of the Sun and Moon is the addition of the equation of either of them to the corresponding argument.

⟨Lc15⟩ *On the opposition of the Sun and Moon*

The opposition of the Sun and Moon and the [corresponding] positions and times are found in a similar way, having also foreseen that, once one has arrived at the investigation of these things, one must first find, by means of an exact [computation] of the equation, the positions [of the Moon] as well as the Sun at the time when the Moon is in its 14th or 15th [day]. Hav-

coequatione prius inveniantur. Quibus inventis, si eorum loca in signis et gradibus et minutis per diametrum oppositionis similia fuerint, tempus et locum oppositionis eorum certa inventione optinebis. Si vero ita non fuerit, omnia quidem modo superiori prout in coniunctione docuimus peragenda sunt. Sed et sciendum est quoniam et hore et minuta interstitii Solis et Lune, interstitium si fuerit, horis et minutis prioris coequationis aut augende erunt aut diminuende. Si igitur Solem precedentem inveneris, horas cum earum minutis ex interstitii per Lune superamen divisione collectas prefate meridiei adicies; et si Luna Solem precesserit eas eidem subtrahendo diminues, ut horas et minuta coniunctionis vel oppositionis Solis et Lune incunctanter agnoscas.

⟨Lc16⟩ *De eclipsi Solis et Lune*

Defectus vero luminum, qui Arabice ‘elkuszuf’ Grece vero ‘eclipsis’ dicitur, qua ratione reperiri queat hoc in loco dicendum est. Primo igitur coniunctio seu oppositio Solis et Lune sollerter notanda eorumque a capite vel cauda Draconis distantia non minus captanda. Secundo siquidem diurni motus Solis et Lune necnon et eorum et Draconis circuli cum dimidio quantitatum ac Lune latitudine in hora coniunctionis seu oppositionis, que videlicet medie eclipsis hora est, investigandi. His autem sollerter supputatione precognitis, ad horam et quantitatem eclipsis certissimam facillime pervenitur.

De his ergo singulis in primis tractemus ut qualiter hec inveniri queant brevi sermone doceamus. Si igitur motum diurnum Solis et Lune velimus colligere, per eorum quidem motus horarios ex tabula horarii motus Solis et Lune, ut iam predocuimus, assumptos facillime reperimus. Acceptis namque ex prefata tabula eorum motibus horariis iuxta horam et minutum coniunctionis seu oppositionis ipsi quidem motus horarii in xxiiii^{or} ducantur quodque inde provenerit motus eorum diurnos monstrabit.

Si igitur circulum Solis ac Lune necnon Draconis circulum reperire intenderis, motum quidem diurnum Solis prius in secunda redactum ac deinde undecies collectum per xx divide fiuntque secunda. Que cum per lx diviseris minuta constituent. Que vero minus fuerint secunda remanent. Hec igitur minuta et secunda iuxta horam coniunctionis sive oppositionis circulum Solis componunt.

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810 fuerit] fuerint *A* 812 et] *om. A* ‖ quoniam] quod *A* 814 earum] eorum *A* 819 De … Lune] *mg. A*; De absis Solis et Lune *mg. S* 820 elkuszuf] elculzuf *L* 821 in] *om. L* ‖ est] erit *L* 826 sollerter] solerunt *A*; sollerciter *S* 827 certissimam] *om. S* 828 primis] primo *A* 830 quidem] *om. A* ‖ horarii] *add.* et *A* 833 seu] sive *A* 835 reperire] invenire *L* 837 fiuntque] fuerintque *A*

ing found these [positions], if they match in being diametrically opposite according to signs, degrees, and minutes, you will [have] obtained the time and the position of their opposition. But if this is not the case, one must carry out everything in the above manner as we have taught for the conjunction. But one should also know that the hours and minutes of the interval between the Sun and Moon, if there should be an interval, will have to be either added to or subtracted from the hours and minutes of the previous equation. If you find the Sun to be ahead, you will consequently add the hours with their minutes that you have gathered from the interval by means of the excess of the Moon to the aforementioned noon; and if the Moon is ahead of the Sun, you will diminish by subtracting them from it so as to discern right away the hours and minutes of the conjunction or opposition of the Sun and Moon.

〈Lc16〉 *On the eclipse of the Sun and Moon*

The method, however, by which one can find the disappearance of the luminaries, which is called *al-kusūf* in Arabic, but *eclipse* in Greek, shall be set out presently. First one must skilfully take note of the conjunction or opposition of the Sun and Moon as well as seize the distances of their ascending or descending node. Second, one must investigate the daily motions of the Sun and Moon as well as their diameters and [the diameter] of the Earth's shadow as well as half of the sizes and the lunar latitude at the moment of the conjunction or opposition, which of course corresponds to the moment of mid-eclipse. Having determined all of this skilfully through calculation, it will be very easy to arrive at the exact time and magnitude of the eclipse.

With regard to these individual things, we shall first discuss in a brief presentation how one can find them. If we wish to gather the daily motion of the Sun and Moon, we very easily find this on the basis of their hourly motions taken from the table of the hourly motions of the Sun and Moon, as we have already taught previously. For having taken their hourly motions from the aforementioned table according to the hour and minute of the conjunction or opposition, one multiplies these motions by 24 and the result will show their daily motions.

If you aim to find the diameter [*circulum*] of the Sun and Moon as well as the diameter of the Earth's shadow [*Draconis*], you must first convert the daily motion of the Sun into seconds and afterwards multiply by 11 and divide by 20 and the result will be in seconds. If these are divided by 60 they make up minutes. But those less [than 60] will remain as seconds. These minutes and seconds, then, form the diameter of the Sun at the moment of the conjunction or opposition.

Motum quoque Lune diurnum in secunda prius redactum deciesque collectum per CC.XLVII divide fiuntque secunda. Que similiter, si per LX diviseris, minuta constituent. Que vero minus fuerint secunda remanent. Hec igitur minuta et secunda non dissimiliter circulum Lune componunt.

Ad circulum vero Draconis componendum motum diurnum Solis in secunda redige ipsaque in XXV multiplicando dissolve. Similiter et motum Lune diurnum in secunda redige ipsaque in octonarium multiplicando dissolve. Quibus dissolutis minorem summam maiori detrahe et quod residuum fuerit per LX divide fiuntque secunda. Que videlicet, cum per LX diviseris, minuta constituent. Que vero minus fuerint secunda remanent. Non minus et hec minuta, si facultas fuerit, per LX divide fiuntque gradus. Que vero minus fuerint minuta remanent. Hi ergo gradus et minuta et secunda circulum Draconis componunt.

Ut ergo dimidium quantitatum colligas, circulum Lune et circulum Draconis simul iunge idque totum per medium divide eiusque totius medium dimidium quantitatum intellige. Qualiter vero latitudo Lune reperiri queat in suo loco iam predocuimus. His igitur inventis ad defectus luminarium eliciendos transeamus. Et primum a defectu Lune incipiamus.

⟨Lc17⟩ *De eclipsi Lune*

Eclipsis alia totalis, alia partialis. Totalis cum solaris seu lunaris spera, vel Lune interiectu, vel umbra terre, nostris aspectibus tota subtrahitur. Partialis vero cum pars quedam obducitur, quedam vero pars splendens relinquitur. Et quoniam Luna ceteris omnibus planetis citior terreque per signa XII transfertur proximior, de eius eclipsi, que videlicet et nobis est citima, prius tractemus.

Cum ergo locum oppositionis ratione certissima notaveris eiusque loci distantiam a capite vel cauda Draconis diligenter assignaveris, si ipsa distantia XII gradibus vel infra a Dracone distiterit, ipsa quidem distantia ubique terrarum eclipsim Lune affirmat. Quod si predicta distantia gradus XII a Dracone excesserit, ipsa omni climati eclipsim denegat. Unde si ipsa ut superius diximus inventa fuerit et eclipsis in tuo climate suspicio inciderit, si dimidio

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841 motum quoque] motumque *LS* ‖ in] *om. A* ‖ prius] *om. L* 842 CC.XLVII] CC.XLVIII *L* ‖ fiuntque] fueritque *A* ‖ LX] 40 *S* 845–846 in … redige] redige in secunda *L* 846–848 Similiter … dissolve] *om. per hom. L* 847 ipsaque] ipsam *A*; ipsa *L* 849 fiuntque] fueritque *A* 850 vero] *om. L* 851–852 per … fuerint] *om. per. hom. S* 852 ergo] vero *L* 855 medium] *om. A* 856 reperiri] reperitur *S* 857 igitur] itaque *A*; ita *L* 859 De … Lune] De eclipsis Solis et Lune *mg. AS* 860 partialis] particularis *S* ‖ cum] est *A* 862 cum] est *A* 864 eclipsi] eclipsis *S* 868 distiterit] destiterit *A*

Also convert the daily motion of the Moon into seconds and multiply them by 10 and divide by 247 and the result is in seconds. If you divide them in the same way by 60, they will make up minutes. But those less [then 60] will remain as seconds. These minutes and seconds will form the diameter of the Moon in the same way [as before].

To form the diameter of the Earth's shadow, however, you must convert the daily motion of the Sun into seconds and dissolve them by multiplying by 25. Likewise, you must convert the daily motion of the Moon into seconds and dissolve them by multiplying by 8. Having dissolved these, you must subtract the smaller sum from the larger one and divide the remainder by 60 and the result is in seconds. Once you divide them by 60, they make up minutes. But those less [than 60] will remain as seconds. By the same token, you must also divide these minutes, if it is possible, by 60 and they become degrees. But those that are less [than 60] remain as minutes. These degrees, minutes, and seconds accordingly form the diameter of the Earth's shadow.

To derive half of the sizes, you must add together the diameter of the Moon and the diameter of the Earth's shadow and divide the whole sum in half and understand one-half of the whole sum to be 'half of the sizes'. But how one can find the latitude of the Moon is something we already taught previously in its [appropriate] place. Having found these things, we accordingly shall move on to deriving the disappearances of the luminaries. And first we shall begin with the disappearance of the Moon.

⟨Lc17⟩ *On the eclipse of the Moon*

An eclipse is either total or partial. It is total when the sphere of the Sun or Moon is completely removed from our gaze as a result of the interjection of either the Moon or the Earth's shadow. It is partial, however, when some part is covered, whereas some other part remains radiant. And since the Moon is carried through the 12 signs at the swiftest rate of all the planets and [is] closest to the Earth, we shall first discuss its eclipse, which is the one nearest to us.

Once you have noted the position of the opposition in a very exact way and have carefully determined the distance of this position from the ascending or descending node, this distance, if it is 12° or less from the node, will affirm everywhere on earth [the possibility of] a lunar eclipse. But if the aforementioned distance exceeds 12° from the node, it denies the occurrence of an eclipse in any climate. Therefore, if [the distance] has been found in accordance with what we said above and there is reason to suspect that an eclipse [will happen] in your climate, if the lunar latitude is equal to or

quantitatum latitudo Lune aut equalis aut maior extiterit, eclipsim negat, minor vero affirmat. Quod si fuerit, latitudo Lune de dimidio quantitatum detrahenda et residuum circulo Lune comparandum. Quod si circulo Lune maius extiterit, eclipsim totalem et cum mora portendit. Si vero ei equale fuerit, eclipsim sed sine mora totalem ostendit. Et si minus fuerit, partialem demonstrat.

Si igitur eclipsis partialis futura fuerit quotaque pars orbis Lune eclipsari debeat scire intenderis, residuum dimidii quantitatum duodecies collectum per circulum Lune divide quodque inde provenerit erunt digiti. Quodque remanserit in LX ducito summamque multiplicationis per circulum Lune secernito eruntque minuta. Quot igitur digitos et minuta inde collegeris, tot digitos et minuta diametri orbis Lune eclipsari non dubites. Quota igitur numeri digitorum ad duodenum numerum proportio fuerit, tota partis Lune eclipsande ad totum corpus lunare futurum erit. Verbi gratia, si III digiti et XX minuta fuerint, quoniam ternarius quarta pars est numeri duodeni, quartam partem lunaris spere cum tertia parte unius duodecime, que scilicet tricesima sexta pars totius lunaris spere est, eclipsandam esse non dubites.

⟨Lc18⟩ *De eclipsi Solis*

Solaris eclipseos cum locus coniunctionis XII gradibus vel infra a Dracone distiterit, si suspicio inciderit, si dimidio quantitatum Lune latitudo occulta maior aut ei equalis extiterit, eclipsim negat, minor vero omnino affirmat. Quod si fuerit, Lune latitudo occulta a dimidio quantitatum detrahatur quodque residuum fuerit circulo Solis comparetur, id est residuum. Quod si autem eo maius aut sibi equale fuerit, totalem, si vero minus, eclipsim partialem designat. Residuum igitur dimidii quantitatum duodecies collige et collectum per circulum Solis divide eruntque digiti. Quodque residuum fuerit in LX ducito et productum per circulum Solis, ut superius, dividito eruntque minuta.

Per hos igitur digitos et minuta iuxta quod superius disseruimus eclipsis quantitatem ratione certissima et absque ullo erroris devio predicere

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875 maius] magis *A* ‖ portendit] protendit *S* 878 futura fuerit] fuerit futura *A* ‖ quotaque] quotacumque *L* 881 ducito] ducentos *A* ‖ summamque] cum namque *S* 882 secernito] se merito *A* ‖ collegeris] colligeris *A* 884 duodenum] duodenarium *L* 885 III] II *AS* 886 duodeni] duodenarii *L* ‖ quartam] quartem *A* 887 duodecime] duodeni *A*; 12 *S* 888 pars] partes *AS* 889 De … solis] *om. A*; *mg. S* 890 locus] locum *ALS* ‖ XII] duodecim *A*; 12 *S* 891 distiterit] destiterit *A* ‖ dimidio] in medio *A* 892 ei] *om. A* 894 residuum] residua *A* 895 autem] *om. A* ‖ maius] minus *AS* ‖ sibi] *om. A* ‖ minus] maius *AS* 896 designat] signat *AL* ‖ dimidii quantitatum] dimidium quantitatum ut *A* 898 eruntque] eritque *A* 901 devio] dimidio *A*

greater than half of the sizes, it denies the occurrence of an eclipse. But it if it is less, it affirms [the eclipse]. In the latter case, one must subtract the lunar latitude from half of the sizes and compare the remainder to the diameter of the Moon. If it is greater than the diameter of the Moon, it foretells an eclipse that is total and with delay. But if it is equal to it, it reveals an eclipse that is total but without delay. And if it is smaller, it shows a partial [eclipse].

If a partial eclipse is about to happen and you aim to know the part of the Moon's orb that is bound to be eclipsed, take 12 times the remainder of half of the sizes and divide it by the diameter of the Moon, and the result will be in digits. And you must multiply the remainder by 60 and divide the product by the diameter of the Moon, and the result will be in minutes. And however many digits and minutes you gather from this, you will not doubt that the Moon is eclipsed by this many digits and minutes of the orb of the Moon. The proportion of the number of digits with respect to 12 will correspond to the [proportion] of the part of the Moon that is bound to become eclipsed with respect to the whole lunar body. For example, if they are 3 digits and 20 minutes, seeing as 3 is the fourth part of 12, you will not doubt that a fourth part of the lunar sphere together with the third part of 1/12th, which is 1/36th of the whole lunar sphere, is bound to become eclipsed.

⟨Lc18⟩ *On the eclipse of the Sun*

If there is reason to suspect that a solar eclipse is about to happen [and] the position of the conjunction is 12° or less from the lunar ascending node, the eclipse is negated if the adjusted [*occulta*] lunar latitude is greater or equal to half of the sizes; but if it is smaller, it wholly affirms [the eclipse]. In the latter case, one must subtract the adjusted lunar latitude from half of the sizes and the remainder must be compared to the diameter of the Sun (i.e., the remainder). If it is greater or equal to it, the eclipse is total, whereas if it is smaller, it indicates a partial eclipse. You must accordingly gather 12 times what remains of half of the sizes and divide the result by the diameter of the Sun and the result will be in digits. And you must multiply the remainder by 60 and divide the product by the diameter of the Sun, as above, and the result will be in minutes.

By means of these digits and minutes you can consequently predict the size of an eclipse with the greatest exactitude and without any error, in

poteris, si Lune latitudinem iuxta quod predocuimus aquilonalem inveneris. Latitudo namque Lune meridiana eclipsim denegat, nisi locus coniunctionis vel oppositionis cum VI gradibus vel infra a Dracone distiterit.

⟨Lc19⟩ *De locis Saturni, Iovis et Martis*

Superiorum vero trium planetarum, Saturni scilicet Iovis et Martis, loca hoc modo invenienda sunt. In primis igitur cuiusvis eorum necnon et Solis medium inveniendum eiusque medium a medio Solis auferendum reliquumque eius argumentum dicendum nec minus et ab eius medio absis illius auferenda quodque residuum fuerit eius centrum dicendum erit. Cum ipso namque centro per lineas numeri in centri equationem intrabitur eiusque ex ea adiunctum notabitur. Et si ipsum centrum maius VI signis fuerit, eius adiunctum sibi, id est centro, adicitur argumentoque subtrahitur; si vero minus, idem eidem subtrahitur argumentoque adicitur; sicque et centrum et argumentum coequatum elicitur.

Et quoniam absque minutis proportionalibus perfici nequit equatio, cum centro iam coequato per lineas numeri in illis fiat ingressio eiusque ex illis adiunctum propria designet inscriptio. Si igitur ipsa minuta diminutionis fuerint, cum argumento quidem coequato per lineas numeri in equationem argumenti et altitudinem maiorem intrandum; si vero augmentationis, in eandem argumenti coequationem altitudinemque minorem simul intrabitur eiusque ex illis adiunctum notabitur. Quotacumque igitur pars minuta proportionalia sexageni numeri extiterint, tota pars accepte altitudinis secernitur. Et si maioris altitudinis fuerit, ipsa equationi argumenti subtrahitur; si vero minoris, eadem eidem adicitur sicque argumenti equatio coequata reperitur. Vel aliter, qualemcumque altitudinem acceperis, ipsam in minuta proportionalia ducito productumque per LX dividito quodque inde provenerit ratione predicta adicito vel subtrahito equationi argumenti.

Si igitur argumentum coequatum minus VI signis fuerit, ipsa eius equata coequatio centro coequato adicitur; si vero maius, ipsa eidem subtrahitur sicque centrum ultimum ex centro coequato efficitur. Si igitur huic centro

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904 VI] sex *L* 905 De … Martis] *om. AS* 906 vero] *om. AL* ‖ planetarum] planete *S* ‖ scilicet] et *S* 909 ab] ad *S* 910 dicendum erit] dicenderit *S* 912 VI] sex *S* 913 id … centro] *om. S* ‖ adicitur] abicitur *S* 914 et] in *S* 917 illis] minutis *add. L* 918 adiunctum] id est minutis *A* ‖ designet] desinuet *A*; designes *S* ‖ diminutionis] diminutioras *S* 919 quidem] *om. AL* ‖ lineas numeri] linea numerali *S* 920 intrandum] *om. S* 920–921 augmentationis] argumentationis *S* 923 minuta … numeri] sexageni numeri minuta proportionalia *L* ‖ extiterint] minuta proportionalia extiterint *add. A* 924 equationi] scilicet per coequationem *A* 928 adicito … argumenti] equationi argumenti adicito vel subtrahito *S* ‖ subtrahito] subtracto *A* 929–930 equata coequatio] equatio coequata *L*

accordance with what we have set out above, provided you find the lunar latitude to be northern according to what we have taught earlier. For a southern lunar latitude negates an eclipse, unless the position of the conjunction or opposition is 6° or less from the lunar ascending node.

⟨Lc19⟩ *On the positions of Saturn, Jupiter, and Mars*

The positions of the three superior planets, which are Saturn, Jupiter, and Mars, must be found by the following method. First one must find the mean [course] of any of them as well as the mean [course] of the Sun and subtract the mean [course of the planet] from the mean [course] of the Sun and call what is left the ‘argument’. One must also subtract [the position] of its apogee from its mean [course] and what remains will have to be called its ‘centre’. For one will use this centre to enter the equation of centre via the column of numbers and take note of the corresponding entry. And if this centre is greater than 6 signs, the entry is added to it (i.e., to the centre) and subtracted from the argument; but if it is less, it is subtracted from [the centre] and added to the argument; and this way one derives the equated centre and argument.

And since the equation cannot be completed without the minutes of proportion, one must use the already-equated centre to enter these [minutes] via the column of numbers and the corresponding entry will be marked by its own inscription. If the minutes are [marked as] subtractive, you must use the equated argument to enter via the column of numbers the equation of the argument and the greater altitude; but if they are [marked as] additive, one will enter the same equation of the argument together with the smaller altitude and take note of the corresponding entries. Whatever part of 60 the minutes of proportion represent, one accepts the same part of the altitude [and] sets it aside. And if it is [a part of] the greater altitude, it is subtracted from the equation of the argument; but if it is [a part of] the smaller one, it is added to it; and this way one finds the equated equation of the argument. Or, [to explain it] differently, whatever altitude you have accepted, you must multiply it by the minutes of proportion and divide the product by 60 and then add or subtract the result from the equation of the argument according to the aforementioned principle.

If the equation of the argument is less than 6 signs, its equated equation is added to the equated centre; but if it is greater, it is subtracted from it; and this way the final centre is derived from the equated centre. If you add

absidem eiusdem planete addideris, ab Ariete computatione habita, locum eiusdem planete proculdubio optinebis. Aut, si mavis, si centri et argumenti coequationes augende sive minuende fuerint, eas simul iungito et si augende fuerint, id totum adiunctum medio cursui planete iungito; si vero minuende, totum id eidem subtrahito sicque locum eiusdem planete accipito. Quod si predicte equationes diverse denominationis fuerint, minorem maiori subtrahe reliquumque, prout eius denominatio dederit, cursui planete vel adice, vel subtrahe, et sic eiusdem locum optine. Idem namque planete locus per utrumque coequandi modum elicitur.

⟨**Lc20**⟩ ***De locis Veneris et Mercurii***

Veneris vero et Mercurii loca ut loca trium planetarum superiorum invenienda sunt, preter quod eorum argumenta ex suis tabulis eliciuntur. Medius namque cursus eorum medius cursus Solis est. Quamobrem eorum argumentis ex suis tabulis argumentalibus assumptis per ipsam et eorum absides et medium cursum Solis prout de tribus planetis superioribus iam disseruimus agendum erit.

⟨**Lc21**⟩ ***De inventione latitudinum V planetarum***

*Latitudin*es vero *trium planetarum superiorum* hoc etiam modo investigare docemus. Cum *cuiuslibet* itaque *eorum* argumento coequato per lineas numeri in latitudinem primam *intra*ndum eiusque adiunctum notandum. Ac *deinde numerus Draconis* eius ipsius *loco eiusdem planete* coequato *coacerva*ndus idque *totum argumentum* latitudinis *dic*endum. Cum *itaque* hoc argumento per lineas numeri *in latitudinem secundam intra*ndum eiusque adiunctum sumendum ipsumque per adiunctum prime latitudinis *divid*endum. *Quod* enim inde provenerit, *ipsum est quod queris*.

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933 aut] sed aut *S* ‖ mavis] maius *A* 934 augende] adiungende *L* 934–935 eas … fuerint] *om. per hom. S* 935 augende] adiungende *L* ‖ adiunctum] *s.l. L* 936 subtrahito] subtracto *A* 937–938 minorem maiori] maiorem minori *A* 941 De … Mercurii] *mg. A*; *om. S* 947 erit] Sciendum quod quantum ad canones hore non inequales debent computari, secundum astrolabium vero inequales. Necesse est igitur convertere horas inequales in horas equales computando XV gradus pro una equali. *add. A* 948 De … planetarum] *om. S* 951 notandum] *om. S* 953 idque] id quod *S* ‖ dicendum] Quod si contingat latitudinem secunda per primam latitudinem non posse dividi, prima latitudo per secundam dividatur. Quod enim inde provenerit latitudo ipsius planete in eadem hora erit, maior numerus superponendus. *add. S* ‖ cum] igitur *add. S* ‖ itaque hoc] hoc itaque *L*

949–964 latitudines … docebit] *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 17 (ed. Suter 1914: 14).

to this centre the apogee of the same planet, [always] counting from Aries, you will doubtlessly obtain the position of this planet. Or, if you prefer, if the equations of the centre and argument must be added or subtracted, add them together, and if they must be added, join this whole sum to the mean course of the planet; but if they must be subtracted, subtract this whole sum from it and this way accept the position of the planet in question. But if the aforementioned equations have different denominations, subtract the smaller from the larger and add or subtract the remainder from the course of the planet, according to its denomination, and this way obtain the position of the same planet. For both methods of computing the equation will result in the same position for the planet.

⟨Lc20⟩ *On the positions of Venus and Mercury*

The positions of Venus and Mercury, however, must be found in the same manner as the positions of the three superior planets, except that their anomalies are derived from their own tables. For the mean course of these [planets] is the mean motion of the Sun. Because of this, one will have to take their anomalies from their respective tables [and] use it and their apogees and the mean course of the Sun to operate just as we have already discussed with regard to the three superior planets.

⟨Lc21⟩ *On finding the latitudes of the five planets*

We shall also teach how to investigate the latitudes of the three superior planets using the following method. One must use the equated argument of a given [planet] to enter the first latitude via the column of numbers and take note of the corresponding entry. And next one must add to the position of the same planet the value of its [ascending] node and call this whole sum the argument of latitude. One must, therefore, use this argument to enter the second latitude via the column of numbers and take what is written there and divide it by the entry for the first latitude. For what results from this is the thing you are looking for.

Pro Venere autem et Mercurio cum cuiuslibet eorum *argument*o coequato per lineas numeri *in latitudinem primam intra*ndum eiusque adiunctum notandum *numerusque Draconis alterutrius* ipsorum et medio cursui Solis *argumento*que coequato unius eorum simul prius coniunctis *coacerva*ndus diceturque id *totum* latitudinis *argumentum*. *Cum eo itaque* argumento per lineas numeri *in latitudinem secundam intra*ndum eiusque adiunctum sumendum ipsumque per adiunctum prime latitudinis *divid*endum. *Quod* enim ex divisione provenerit optatum docebit.

⟨Lc22⟩ ***De inventione retrogradationis, stationis et directionis V planetarum***

Sciendum quoque est *quibus horis* quinque *planete progredientes*, *quibus retrogradi*, *quibus* etiam *stationarii* inveniantur. Cum *cuiuslibet* ergo eorum *centr*o coequato per lineas numeri in *station*em *prim*am eiusdem planete *intra*ndum *eiusque adiunctum nota*ndum. Eritque statio prima. *Deinde stationem prima*m XII *signis* subtrahe *quod*que *residuum fuerit statio secunda* nominandum. Si igitur *argumentum* coequatum *i*ll*ius planete* uni *stationum* in signis et signorum partibus *equale fuerit*, *in ea stationarius e*rit. Quod si *inter utr*u*mque maius videlicet prima minusque secunda* extiterit, *retrograd*ando recedit. *Alioquin directe progredi* iudicandus erit.

⟨Lc23⟩ ***De quantitate temporum retrogradationis, stationis, directionis quinque planetarum***

Si vero quanto temporis spatio ipsi etiam progredientes vel *retrogradi fuerint* nosse *desideras*, si eorum *quilibet retrogradus fuerit*, eius statio prima ab ipsius argumento coequato auferenda erit. Ipsum enim argumenti residuum per motum ipsius planete absque equatione diurnum si divisum fuerit, temporis spatium sue retrogradationis manifeste monstrabit. Quod si ipsum argumentum stationi secunde subtractum fuerit, id quod residuum fuerit, si per predictum motum diurnum divisum fuerit, temporis spatium secunde stationis finemque retrogradationis indicabit.

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957 pro] cum *AL* ‖ cuiuslibet] quolibet *L* 959 alterutrius] alterutriusque *AL* 960 argumentoque] argumento et *A* 961 diceturque] dicetur quod *S* 965–966 De … planetarum] *mg. S* 965 stationis] stationum *A* ‖ V] quinque *A* 969 stationem] statione *A* ‖ eiusdem] eius *A* 971 statio secunda] stationem secundam *L* 973 partibus] gradibus *L* 976–977 De … planetarum] *om. A*; *mg. S* 979 quilibet] quislibet *S* 980 Ipsum] Ipsumque *S* ‖ enim] etenim *A* 983 id] idque *A*

967–975 sciendum … erit] *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 13 (ed. Suter 1914: 12).
978–979 si … fuerit] *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 14 (ed. Suter 1914: 12).

But for Venus and Mercury one must use the equated argument of [the planet] in question to enter the first latitude via the column of numbers and take note of the corresponding entry; and the value of the [ascending] node of one of [these two planets] must be added to the mean course of the Sun as well as the equated argument of one of them, after these have previously been added together, and this whole sum will be called the argument of latitude. One must, therefore, use this argument to enter the second latitude via the column of numbers and take what is written there and divide it by the entry for the first latitude. For what results from this division will teach the thing that is wanted.

〈Lc22〉 *On finding the retrogradation, station, and direct* [*motion*] *of the five planets*

One should also know in which hours the five planets are found to be direct, in which they are retrograde, and in which they are stationary. One must accordingly use the equated centre of a given [planet] to enter the first station via the column of numbers and take note of the corresponding entry. And this will be the first station. Afterwards you must subtract the first station from 12 signs and the remainder must be called the second station. If the equated argument of this planet is equal to one of the stations according to signs and parts of the signs, it follows that it will be stationary at this point. But if it is between the two, such that it is greater than the first and smaller than the second, it retreats by being retrograde. Otherwise it will have to be considered direct.

〈Lc23〉 *On the duration for which the five planets are retrograde, stationary, direct*

But if you also desire to know the span of time during which they are forward-moving or retrograde, [and] a given [planet] happens to be retrograde, one must subtract its first station from its equated argument. For if the remainder of this argument is divided by the daily non-equated motion of this planet, it will plainly show the duration of its retrogradation. But if this argument is subtracted from the second station, the remainder of this, if it is divided by the daily motion, will indicate the time [until the] second station and the end of the retrogradation.

Quod si idem planeta directus fuerit spatiumque temporis a quo dirigi inceperit usque in presentem horam nosse volueris, statio quidem secunda a predicto eius argumento auferenda erit. Quod enim residuum fuerit, per predictum motum diurnum divisum temporis spatium prefate directionis ipsum indicabit. Si vero ipsum argumentum maius vel minus utraque statione stationi prime subtractum fuerit, eius residuum per predictum motum diurnum dividendum erit. Quod enim ex divisione provenerit, tempus prime stationis finemque eius directionis et initium retrogradationis ostendet.

Motus autem planetarum quinque iuxta predictum statum diurnum hac ratione colligitur. Cuiuscumque igitur planetarum quinque motum diurnum scire volueris, eius motum medialem unius diei a mediali Solis motu in una die auferas et quod residuum fuerit diurnum motum eiusdem planete monstrabit. Exempli gratia, si Saturni medialem motum unius diei, id est duo minuta, a mediali Solis motu unius diei, id est a quinquaginta novem minutis et viii secundis, diminuas, quinquaginta vii minuta et viii secunda erunt residua, per que videlicet predicte differentie dividende erunt, hoc tamen excepto quod mediales diurni motus Veneris et Mercurii ex suis tabulis argumentalibus accipiuntur.

Et ne erroris nebula lectoris animum videatur obtegere, argumentum Saturni coequatum eiusque primam et secundam stationen in exemplum proponimus. Eius itaque argumentum cifre in signis, unum in gradibus, duo in minutis, quatuor in secundis contineat eiusque statio prima cifre in signis, cifre in gradibus, unum in minutis, duo in secundis concludat. Sed et eius statio secunda unum in signis, duo in gradibus, quatuor in minutis atque octo in secundis optineat. Iuxta hanc igitur et argumenti et stationum positionem Saturnus retrogradus invenitur. Eius namque argumentum maius prima minusque secunda statione reperitur. Prima igitur statio, id est unum minutum duoque secunda, ab argumento, id est ab uno gradu et duobus minutis et quatuor secundis, auferatur. Si igitur argumenti residuum, id est gradum unum unumque minutum et duo secunda, per Saturni motum diurnum, id est per lvii minuta et viii secunda diviseris ex divisione spatium unius diei ab initio retrogradationis usque in horam coequationis colliges ducentis xxxiiii secundis ex divisione remanentibus, que videlicet si per cxlviii diviseris divisionisque residuum in lx duxeris et ductionis summam per cxlviii item diviseris, unam horam et xxxiiii minuta hore unius aggregabis. Unde ab initio retrogradationis usque in presens tempus unum diem unamque horam et xxxiiii minuta hore unius colliges. Quod si per hoc argu-

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987 inceperit] incipierit *A* 998–999 id est … diei] *om. per hom. S* 1000 vii] *om. S* 1007 cifre] X *A*; o *S* 1008 cifre] X *A*; o *S* 1022 xxxiiii] xxxv *A*

But if the planet is direct and you wish to know the span of time between the onset of its direct motion and the present hour, one will have to subtract the second station from its aforementioned argument. For if the remainder is divided by the aforementioned daily motion, it will indicate the duration of the aforementioned direct motion. But if this argument, being greater or smaller than either station,[2] is subtracted from the first station, its remainder will have to be divided by the aforementioned daily motion. For what comes out of the division will show the time [until] the first station and the end of the direct motion and beginning of the retrogradation.

But the motion of the five planets according to the aforementioned daily position is derived in the following manner. Subtract the mean motion in one day of any planet whose daily motion you wish to know from the mean motion of the Sun in one day and the remainder will show the daily motion of this planet. For example, if you subtract the daily mean motion of Saturn, which is 0;2°, from the daily mean motion of the Sun, which is 0;59,8°, there will be left 0;57,8°, which is the amount by which the aforementioned differences will have to be divided, excepting the fact that the daily mean motions of Venus and Mercury are taken from their own tables.

And to ensure the fog of error does not engulf the reader's mind, we put forward the example of the equated argument of Saturn and its first and second station. Let its argument contain 0;0,2,4° and its first station 0;0,0,2°. Its second station, however, shall have 1;2,4,8°. According to this position, then, of both the argument and the stations, Saturn is discovered to be retrograde. For its argument is found to be larger than the first and smaller than the second station. Let the first station (i.e., 0;1,2°) accordingly be subtracted from the argument (i.e., 1;2°). If you divide the remainder of the argument (i.e., 1;1,2°) by the daily motion of Saturn (i.e., by 0;57,8°), you will derive from this division the span of one day from the beginning of the retrogradation to the hour when the equation was made, with 234 seconds remaining from the division. If you divide these by 148 and multiply the remainder of the division by 60 and again divide the product by 148, you will add 1 hour and 34 minutes of an hour. You will, as a consequence, gather 1 day and 1 hour and 34 minutes from the beginning of the retrogradation to the present time.

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[2] In the scenario at hand, the instantaneous value of the anomaly will exceed that of the second station (*modulo* 360°) and be smaller than that for the first station.

mentum et has stationes cetera exequi volueris, prout superius disseruimus agendum erit.

Sed et V planetarum motus diurni per quos predicta debet fieri divisio sunt: Saturni videlicet motus diurnus minuta sunt LVII, secunda VIII; Iovis minuta LIIII, secunda IX; Martis minuta XXVII, secunda XLI; Veneris minuta XXXVII, secunda 0; Mercurii gradus III, minuta VI, secunda XXIIII. Ut ergo quot dies et hore et minuta a principio directionis seu retrogradationis in presens tempus transeant certa computatione colligas, cum argumenti coequati residuum per motum diurnum planete diviseris divisionisque residuum in secunda redactum per CXLVIII secunda etiam segregabis. Quod enim ex segregatione provenerit, horas computabis. Quod post segregationem remanserit, in LX multiplicabis quodque inde provenerit per CXLVIII item segregabis. Quod enim ex segregatione provenerit, hore minuta nuncupabis. Sic igitur et dies et hora et minuta ab initio directionis seu retrogradationis planete usque in presens tempus certa computatione invenies.

⟨Lc24⟩ ***De conversione horarum equalium in horas inequales ad horam et eius partem certissimam coniunctionis et oppositionis Solis et Lune eliciendam***

Cum igitur Solem et Lunam ad meridiem alicuius diei coequaveris, unumquodque eorum alterum precessisse inveneris, cum ex eorum interstitio horas equales et minuta collegeris et horarum quantitatem eiusdem diei et noctis precedentis sive subsequentis agnoveris, horas equales eorum interstitii in horas inequales cuiusvis diei et noctis eiusdem climatis hoc modo vertere poteris. Horas ergo equales interstiiti cum suis minutis, si qua fuerint, primum in gradus converte. Et ex illis omnibus gradus sex horarum diei coniunctionis subtrahe gradusque residuos per quantitatem unius hore noctis subsequentis divide et quot horas ex divisione collegeris sex horis diei superius demptis adice et sic horas diei et noctis sequentis incunctanter agnosce.

Ita dico si ipsa coniunctio post meridiem et Solis occasum forte acciderit. Quod si gradus sex horarum eiusdem diei ex gradibus horarum equalium interstitii subtrahere nequiveris, gradus horarum equalium interstitii per quantitatem unius hore eiusdem diei divide et, si quid residuum fuerit, quantitati unius diei ipsius hore comparabis ut et horas integras et minuta incunctanter agnoscas. Has igitur horas et earum partes, sive diurne simul et

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1026 videlicet] et *add. S* 1040 eliciendam] *mg. S* 1047 sex] 6 *AS* 1049–1050 superius demptis] demptis superius *S* 1051–1052 acciderit] accidit *A* 1052 sex] 6 *AS* ‖ horarum] hore *S* ‖ diei] dierum *AS* 1053 subtrahere] subtrahe *A* 1054 diei] die *A* 1055 diei] *om. A* ‖ ipsius hore] hore ipsius *A*

But if you wish to arrive at the other [parameters] by means of the argument and these stations, one will have to proceed as we have discussed above.

But the daily motions of the five planets that must be used to make the aforementioned division are [as follows]: the daily motion of Saturn is 0;57,8°; that of Jupiter is 0;54,9°; that of Mars 0;27,41°; that of Venus 0;37,0°; that of Mercury 3;6,24°. In order for you to gather by exact computation the number of days, hours, and minutes between the beginning of the direct or retrograde motion and the present time, you must accordingly divide the remainder of the equated argument by the daily motion of the planet and also divide by 148 the remainder of the division after having converted it into seconds. For what comes out of this division, you will count as hours. What remains after the division, you will multiply by 60 and what comes out of this you will again divide by 148. For what comes out of the division, you will call the minutes of an hour. This, then, is how you will find the days, hours, and minutes from the beginning of the direct or retrograde motion to the present time by exact computation.

⟨Lc24⟩ *On how to convert equal hours into unequal hours in order to derive the exact hour and its part of a conjunction and opposition of the Sun and Moon*

If you have equated the Sun and the Moon for the noon of a given day [and] have found that one is ahead of the other, [and] if you have [then] gathered the equal hours and minutes from the interval between them and have [also] discerned the length of the hours of the same day and the preceding or following night, you will be able to convert the equal hours in this interval into the unequal hours of any day and night of the same climate by the following method. First you must convert the equal hours of the interval together with their minutes, if there were any, into degrees. And you must subtract from them all the degrees of 6 hours of the day of the conjunction and divide the degrees that remain by the length of one hour of the following night and add the number of hours that you will have obtained from the division to the 6 hours of the day that have been taken away previously and this way discern right away the hours of the day and the following night.

What I say here applies to cases where the conjunction occurs after noon and sunset. But if you are not able to subtract the degrees of 6 hours of the same day from the degrees of the equal hours in the interval, you must divide the degrees of the equal hours in the interval by the length of one hour of the same day, and if something remains, you will compare it to the length of one hour of this day so as to discern right away the whole hours and minutes. These hours, then, and their parts, be they diurnal as well as nocturnal or

nocturne sint, sive tantum diurne, si Sol Lunam transierit, supra meridiem ad quam Solem et Lunam prius coequasti aggregabis ut horam eiusque partem qua videlicet ipsa coniunctio futura sit certissime agnoscas.

Quod si Luna Solem preterierit, eorum conventum ante meridiem ipsius diei fore non dubites. Unde et omnia ut supradictum est peragenda erunt, hoc etiam addito ut cum horas et earum minuta ex divisione collegeris, ipsas ex xxiiii horis subtrahis ut iuxta horarum residuarum numerum a meridie diei precedentis computatione habita horam certam coniunctionis invenies. Iuxta ergo hanc horam, sive ipsa ante sive post meridiem fuerit, horoscopus coniunctionis notandus erit.

Sed et si ipsa coniunctio post meridiem et ante Solis occasum vel ante meridiem et post Solis ortum fuerit, quod videlicet ex numero horarum equalium interstitii accipitur ipsis horis equalibus cum suis minutis in gradus conversis, quotquot gradus ex earum conversione colligeris per quantitatem unius hore eiusdem diei divide; et quot horas ex divisione collegeris meridiei eiusdem diei ratione predicta cum suis partibus, vel adice, vel subtrahe; et hoc modo certam horam coniunctionis intellige.

⟨Lc25⟩ *De planetarum coniunctionis inventione*

Si quando levis quilibet planeta cuilibet tardo coniungi debeat scire intenderis, eorum quidem loca iuxta coequandi rationem prius investigabis. Quod si eorum locus in signo aliquo et gradu et minuto unus idemque fuerit, optatum tenebis. Et si unum eorum alterum precessisse inveneris, eorum interstitium certissime notabis. Quod cum notaveris, ipsum quidem iuxta eorundem circulorum proportionem dividi oportebit. Assumpta una divisionis proportione per motum planete tardioris in una hora ipsa dividenda erit ut quot horis ipsi suum interstitium perficiant agnoscas. Has igitur horas cum suis partibus horis coequationis adicies vel diminues. Nam si tardior precesserit, addende, si vero levior, cum partibus suis erunt minuende. Et sic horam coniunctionis eorum incunctanter habebis.

1060 preterierit] preteriit *S* 1063 subtrahis] subtrahes *A* 1065 ante] aut *AS* 1072 meridiei] *om. S* 1074 De … inventione] *mg. A*; *om. S* 1077 idemque] idem *S* 1082 agnoscas] agnoscant *A* 1085 habebis] Omnis planeta qui fuit ante aliquem cardinem aut ante aliam aliqua domus plus 5 gradibus in eo cardine aut ea domo esse non iudicatur. Item omnis planeta qui minus 5 gradibus in suo signo extiterit ⟨non⟩ iuxta minuta eiusdem signi, sed potius iuxta minuta signi precedentis effectum descernit. Ut, verbi gratia, si Sol in primo aut secundo aut tertio aut in quarto gradu Arietis extiterit, iuxta minuta signi Piscis per Solem iudicandum erit. Ergo iuxta hanc sententiam planetarum loca in omni figura ponenda sunt. Sinistra pars ascendentis est sub terra. *add. S*

diurnal only, you will add to the noon for which you previously computed the equation of the Sun and Moon so as to discern with full exactitude the hour and its part at which the conjunction will take place—provided the Sun was ahead of the Moon.

But if the Moon was ahead of the Sun, you will not doubt that their conjunction took place before the noon of this day. One must accordingly carry out everything as has been said above, with the additional step that, once you have gathered via division the hours and their minutes, you must subtract them from 24 hours so as to find the exact hour of the conjunction by counting the number of hours that remain since the noon of the preceding day. According to this hour, then, whether it be before or after noon, one will have to note the ascendant [*horoscopus*] of the conjunction.

But also in cases where this conjunction took place after noon and before sunset or before noon and after sunrise, you must convert into degrees what is taken from the number of equal hours of the interval together with its minutes and divide whatever number of degrees you gather from this conversion by the length of one hour of the same day; and the number of hours with their parts that you will have obtained from the division must either be either added to or subtracted from the noon of the same day; and this way you shall gain knowledge of the exact hour of the conjunction.

⟨Lc25⟩ *On finding a conjunction of the planets*

But if your aim is to know when some fast-moving planet is due to undergo a conjunction with some slow-moving one, you will first investigate their positions according to the method of [computing the] equation. If their position is one and the same according to some sign, degree, and minute, you will [already] have the thing that is wanted. And if you find that one was ahead of the other, you will take note of their interval with full exactitude. Once you have taken note of this, it will be necessary to divide it according to the ratio between their paths [*circulorum*]. Having taken one portion of the division, it will have to be divided by the hourly motion of the slower-moving planet so as to discern the number of hours in which they complete their interval. You will, therefore, add or subtract these hours with their parts from the hour for which the equation was computed. For they will have to be added together with their parts, if the slower-moving one is ahead, but subtracted, if it is the fasting-moving one. And this way you will arrive right away at the moment of their conjunction.

Commentary

*Lc*1

Robert of Chester begins *Lc* by addressing the differences in calendrical structure that set the Tables of London included in this part of the *Liber canonum* apart from the Toledan Tables of the preceding part, which is now lost. The first point he makes (ll. 9–27) is that the Tables of London possess a special advantage in that they put the beginning of the year on 1 March. This makes them easier to handle in bissextile years, seeing as the additional day is here intercalated towards the end of the final month of the year. Robert's version of the Toledan Tables, by contrast, placed the beginning of the year on 1 January, which made it necessary to apply two different expanded-year entries to the same bissextile year: one for the months of January and February and another for the remaining months (see pp. 216–217).

As was already the case in the Tables of Pisa, each day in Robert's London tables is reckoned from "end of the sixth hour and the beginning of the seventh" (ll. 10–11: *in fine hore sexte et initio septime*), which must be understood as referring to noon of the same day. In this respect, the Tables of Pisa and London differ from many Islamic sets of astronomical tables, among them the Toledan Tables, where the convention is to reckon calendrical dates from the noon that preceded the civil date. That there is, in effect, a 24-hour difference between the Toledan Tables and the Tables of London is noted by the glossator to the Toledan canons 'Ca' (*Scito quod annus lunaris* …) included in *S*.[1] His probable source of information was one of the subsequent items in the same codex, a treatise beginning *Diversi astrologi secundum diversos annos* … and attributed to one Robert of Northampton.[2] Although mainly concerned with the Toledan Tables, the author wants his readers to know that

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[1] *S*, fol. 31va (left margin): "Patet quod dies computandi sunt a fine et non a principio. In tabulis London⟨iensibus⟩ ponitur initium diei in meridie sui ipsius." The canons to the London tables are also mentioned in the bottom margin of *S*, fol. 31^{rb}.

[2] *S*, fols. 40^{v}, 42^{r}–61^{v} (s. XIII; *Canones magistri Roberti de Northampton*). This is text VIII noted in Mercier 1991: 20. Other copies I have seen are anonymous or attribute the text to Roger of Hereford: Città del Vaticano, Biblioteca Apostolica Vaticana, Vat. lat. 3133, fols. 1ra–19^{vb} (s. XIV; incomplete; anonymous and untitled); Oxford, Bodleian Library, Bodley 300, fols. 1ra–19va (s. XV^{in}; *Theorica magistri Rogeri Herfordensis*); Oxford, Bodleian Library, Digby 168, fols. 69^{vb}–83^{vb} (s. XIV; *Theorica Rogeri Herfordensis*); Paris, Bibliothèque nationale de France, lat. 15171, fols. 136^{r}–157^{v} (s. XIV/XV; anonymous and untitled). Briefer excerpts and fragments appear in *D*, fol. 35^{v} (s. XIV$^{1/2}$); S_2, fol. 203^{v} (s. XIV^{med}; attr. Roger of Hereford);

> according to all tables that I have seen thus far, the beginning of a given day is placed at the noon of the preceding day and the end or completion at its own noon. The exception are the tables made for London, according to which the beginning of the day is placed at its own noon and the end at the noon of the following day.[3]

One peculiarity of the London tables as originally included in *Lc* is that the tables for collected years did not spell out the full number of years AD to which each of its lines referred. Instead, the first entry was simply marked *radix*, which users were expected to identify with 1149 completed years, or 1 March 1150 (ll. 105–107). Given that the collected years were meant to increase by 20-year steps, one would expect the subsequent lines to have been marked with *20*, *40*, *60* etc. This is not the case in the tables preserved in *L* and *T*, where the years following the *radix* are written as *29*, *49*, *69* etc. As Robert explains at the end of *Lc*1 (ll. 116–125), this addition of 9 was made intentionally as a way of reminding users that the corresponding number of years AD must end on 9 (i.e., 1169, 1189, 1209 etc.). In *L*, a note placed ahead of the mean-motion tables makes it clear that 1141 years must be added to the number written at the head of each line to identify the (incomplete) year AD.[4] The scribe who excerpted some of the mean-motion tables into *D* was clearly unaware of this rule and instead assumed that the years *29*, *49*, *69* etc. written in his exemplar were shorthand for *1029*, *1049*, *1069* etc.[5]

Erfurt, Universitätsbibliothek, Dep. Erf. CA 4° 352, fols. 94$^{\mathrm{ra}}$–96$^{\mathrm{rb}}$ (s. XIV$^{1/2}$); Oxford, Bodleian Library, Digby 17, fol. 156$^{\mathrm{r}}$ (s. XVI; attr. Robert of Chester). For further discussions/mentions of this text, see Duhem 1915: 501–519 (suggests Roger Bacon as author); Lipton 1978: 169; North 1986: 115, 117 (accepts attribution to Roger of Hereford); Pedersen (Fritz) 2002: ii. 340–341.

[3] *S*, fol. 42$^{\mathrm{v}}$: “Et scito quod secundum omnes tabulas quas hucusque vidi ponitur initium diei cuiusque in meridie precedentis diei et finis sive perfectio in meridie sui ipsius. Preter quam secundum tabulas ad Londonias factas, secundum quas ponitur initium diei in meridie sui ipsius et finis in meridie diei sequentis.” Parts of this passage are underlined in the manuscript.

[4] *L*, fol. 7$^{\mathrm{rb}}$: “Subtracti sunt a tabula sequenti M.C.XLI quibus si addatur numerus anni collecti, id est 29 vel 49 vel simile, et numerus anni residui qui sumitur ad equandum, habebis annos ab incarnatione domini.” The existence of this note is ignored by North 2002: 16, who nevertheless infers the correct *radix*. The issue is discussed in more detail in a textual addition to *Lc*1 in *S* (fols. 86$^{\mathrm{v}}$–87$^{\mathrm{r}}$), which must have its origin in a marginal gloss. See the critical apparatus for l. 104 in the edition below.

[5] The same kind of confusion is evident in Chabás 2019: 118, who assumes that the Tables of London begin with 1009 collected years and ends up drawing incorrect conclusions about the longitude difference between the Tables of London and Tables of Pisa.

The correct understanding of the chronological framework of the London tables is the subject of an isolated note in MS Oxford, Bodleian Library, Digby 20, fol. 61^{r} (s. XIII), where it is found adjacent to a copy of the aforementioned Toledan canons 'Ca' (fols. 35^{r}–60^{v}). The author of this note begins by affirming the date of Christ's birth as Saturday, 25 December 1 BC, a view he attributes to Petrus Alfonsi (*Petro Anphus*). He further notes that the years in the London tables, which employ years of the Lord, put their *radix* or root-date at 1 March 1149. This, he explains, must be understood as meaning that "the *radix* begins to grow in this year, but finishes in the following year, namely, in AD 1150" (*sic, dico, intelligendum quod in illo anno incipit radix crescere, sed terminatur anno sequenti, scilicet anno domini 1150*). While this would seem to evince a placement of the starting date one year too early, the author of the note immediately goes on to state that the first expanded year (*annus residuus*) runs from 1150 to 1151, which agrees with a conventional understanding of these tables. The remainder of the same note is devoted to the parameters of a partial lunar eclipse the author had computed for 29 September 1205, presumably on the basis of the London tables. From the fact that he mentions this eclipse as a past event, a *terminus post quem* for his time of writing emerges.[6]

The time intervals that could reasonably be used to construct a collected-year table on the basis of the Julian calendar were effectively constrained by its leap-year cycle. It meant that multiples of 4 years were required to guarantee a steady increase of mean longitude from one line to the next. From a calendrical or computistical perspective, it could seem especially advantageous to operate with the 28 years of the so-called 'solar cycle', which arose from multiplying the 4-year cycle of leap years by the 7 days of the week. The 7 × 4 = 28 years in this cycle equalled 1461 complete weeks, ensuring that the correlations between Julian dates and days of the week recurred identically with each iteration of the cycle. By extension, all entries in a collected-year table founded on 28-year intervals were going to share a single day of the week (ll. 56–76). In explaining this calendrical principle, Robert commits the odd mistake of ignoring the Julian bissextile intercalation. He accordingly reckons each year as consisting of 52 weeks and one surplus day, which after 28 years add up to 1460 complete weeks (ll. 67–73). The actual of number of weeks in a 28-year cycle is 1461 owing to the fact that the same span of years contains 7 bissextile days.

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[6] MS Oxford, Bodleian Library, Digby 20, fol. 61^{r}: "Quicque alii dicant, ego dico cum Petro Anpus quod dominus Ihesus Christus natus fuit anno bissextili, ciclo nostro primo, littera dominicali C. Natus est ergo die Sabbati. Secundum hoc ergo dico quod radix tabularum super Lond⟨onias⟩ quam ipsi dicunt fundata esse supra diem Martii anno domini M.C.XLIX sic, dico, intelligendum quod in illo anno incipit radix crescere, sed terminatur anno sequenti, scilicet anno domini 1150. Et tunc incipit primus annus residuus in eodem quadragesimo [*sic*] et terminatur 1151. Secundum hanc computationem transactis penitus annis domini M.CC.4 et de quinto anno septem diebus natalis et postea mensibus 8 et diebus 28 in die sancti Michaelis secundum kalendarium fuit modico oppositio. Non oportet eam strictius computare. Eodem ergo die hora meridiei fuit motus capitis Draconis in octavo gradu Arietis. Verus locus Solis continebat sex signa, 13 gradus, 8 minuta, 9 secunda. Verus locus Lune nullum ⟨signum⟩, gradus 9, 21 minuta, secunda 13. Hora octava post meridiem vera oppositio. Et eclipsis Lune manifesta. Et obscurati digiti 9."

The mentioned cyclical feature of the 28-year interval in all likelihood explains why it had been employed in creating the Christian adaptation of the Toledan Tables included in the first part of Robert's *Liber canonum* (see § 5). By contrast, the 20-year intervals that characterized the Tables of Pisa and London provided no comparable advantage, seeing as 20 Julian years contained 1043 weeks with a surplus of 4 days. Robert nevertheless assumed that there had to be a deeper meaning behind this interval and tried to discover it through another questionable piece of arithmetical reasoning. As he explained in *Lc*1, the collected years in the Tables of London did not simply increase by steps of 20 years, but by "29 and 20 years" (ll. 56–57: *XXIX et XX … collectio*). This was a reference to the fact that the number written at the head of the third line of each collected-year table was formed by adding 20 to 29. Robert claimed that the sum of these numbers, 49, contained 2548 complete weeks with no remainder of days or hours (ll. 77–81). To arrive at this number, he multiplied by 49 the 52 whole weeks contained in a Julian year while completely ignoring that common years added 1 day on top, while leap years added 2.

Flaws in Robert's arithmetic are also apparent in an earlier passage that discusses the relation between the Julian year of 365 ¼ days and the actual length of a solar year (ll. 28–55). His computation of the latter assumes that the Sun moves at a precise rate of 0;59,8° per day, which is the daily value listed in the Tables of Pisa and London. Operating with this simplified value, Robert deduces that at the end of 360 days the Sun will have to traverse another $360 \times (1^\circ - 0;59,8^\circ/\mathrm{d})$ or $360 \times 0;0,52^\circ = 5;12^\circ$ to complete a full revolution of the zodiac. To calculate the corresponding time, he converts 5;12° into 18,720 seconds of arc and divides this number by the hourly solar motion. He takes this hourly rate of motion to be 148 seconds of arc, which again matches the corresponding entry in the Tables of London (0;2,28°). Dividing 18,720 seconds by 148 seconds per hour yields 126 hours with a remainder of 72. Robert converts these 126 hours into 5 days, 6 hours. As for the 72 seconds that have remained from the previous division, Robert claims that they are equivalent to 1/900th + 12/5400th of an hour, which would add up to 1/300th of an hour or 0;0,12h =

0;0,0,30d. In actual fact, 72 seconds amount to 1/50th of an hour or 1/1200th of a day. It is not clear how Robert arrived at his numbers, or why they are off by a factor of 6.

Besides the 28-year and 20-year formats derived from the Julian calendar, astronomers in Robert's day were also familiar with mean-motion tables that operated with a 30-year cycle founded on the Islamic lunar calendar. Rather than following the 7-day week, this cycle was implied by the length of an average lunar year, which in Islamic astronomical tables was reckoned as 354 + 1/5 + 1/6 or 354 11/30 days (= 354;22d). Multiplying this year length by 30 yielded 10,631 exact days, which were distributed over 30 lunar years consisting of 12 months each. One source that would account for Robert's knowledge of this 30-year cycle, as displayed at the end of *Lc*1 (ll. 82–99), is Adelard of Bath's Latin translation of Maslama al-Majrīṭī's recension of the *Sindhind Zīj* of al-Khwārizmī (see pp. 198–200). Included in this translation are a brief chapter explaining the structure of the cyclical version of the Islamic calendar as well as a table for finding the day of the week at the beginning of each month.[7] Robert's revision of Adelard's translation, as preserved in *M* (fol. 8^{rb}), supplements this chapter with a small table showing the length of each Islamic month (30 or 29 days). The same manuscript features a table for the conversion between Islamic and Christian years (fol. 9^{r}), although this may be a later scribal addition.

*Lc*2

Following on from his discussion of the Islamic lunar calendar and its 30-year cycle in *Lc*1, Robert adds two full chapters on how to convert its dates into the Christian calendrical format employed in the *Liber canonum* as well as vice versa. He prefaces his instructions on calendrical conversions with some general remarks about the divergent beginnings of the calendrical year observed among different 'nations'. When it comes to the solar calendar in use among Christians, he acknowledges the first days of January, March, September, and October as possible starting points (ll. 128–129). The use of the conventional beginning on 1 January characterized the Toledan Tables included in the first part of the *Liber canonum* as well as of the Tables of Marseilles in Raymond of Marseilles's *Liber cursuum planetarum*, which were probably related to the former (see pp. 216–217). Another example Robert may have come across is an undated Latin recension of the tables of al-Khwārizmī, where the initial *radix* is 1 January AD 1020.[8] In one manuscript, the tables are accompanied by canons dated 1145.[9]

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[7] *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 1, 4; Tab. 2 (ed. Suter 1914: 2, 5, 110). See also Ibn al-Muthannā, *Commentary on the Tables of al-Khwārizmī*, trans. Hugo Sanctelliensis (ed. Millás Vendrell 1963: 96–97, 101–103); Ca1–3, 15, 24, 78a–c (ed. Pedersen [Fritz] 2002: i. 216, 220–222, 224, 246–248); Cb7–9, 17 (ed. Pedersen [Fritz] 2002: ii. 382–384, 386); Cc1–31 (ed. Pedersen [Fritz] 2002: ii. 588–602); *Collatio Compoti Romani et Arabici*, §§ 2, 9 (ed. Nothaft 2015: 201–202, 204); Nothaft 2014b.

Tables that instead began the year on 1 March included Robert's own Tables of London as well as their model and precursor, the Tables of Pisa. Another relevant example are the tables in the *zīj* of al-Battānī, whose authority Robert invokes at the start of *Lc*1. A claim to the effect that the Julian or 'Roman' year begins on 1 October can be found in the canons to Adelard of Bath's translation of the *zīj* of al-Khwārizmī.[10] The same principle is in fact already observed in Petrus Alfonsi's Latin translation of the Khwārizmīan tables, which is datable to AD 1116.[11] It is less clear what example Robert had in mind when he mentioned a beginning of 1 September (l. 129). One possibility is that he was familiar with the almanac of Azarquiel or Ibn al-Zarqālluh, a 'perpetual' almanac of the late eleventh century that began each year on this date.[12] Of the two known Latin versions of this almanac, one appears to go back to the 1150s, if not earlier.[13]

According to Robert, there were also those who began the (lunar) year with the first sighting of the new moon crescent, whereas others chose the moment when the Sun and Moon were in conjunction (ll. 129–130). The former practice characterized the Islamic lunar calendar in all religious contexts, notwithstanding the fact that the version used in astronomical tables followed a fixed cyclical form. Another feature of such tables was that they moved the epoch of the Hijri era one day earlier, to 15 July AD 622, which brought the first day of the lunar year closer to the conjunction of the luminaries. By contrast, the 'civil' beginning of the Hijri era was 16 July, in line with the visibility criterion of the corresponding calendar.[14] Robert may have had this distinction between epochs in mind when he wrote down his remark about the different beginnings of the lunar year. Alternatively, he may have been thinking of the Jewish calendar, whose contemporary rabbinic version relied on calculations of the *molad* or mean conjunction. It seems possible, moreover, that he thought along the same lines as the English author of an anonymous *Collatio Compoti Romani et Arabici*, which appears to date from the second quarter of the twelfth century. According to this text, the lunar reckonings of the Romans (i.e., Latin Christians) and Arabs differed in that the former defined the new moon as the moment of first visibility, the latter as the moment of conjunction.[15]

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[8] MSS Darmstadt, Universitäts- und Landesbibliothek, 765, fols. 204^{r}–215^{ra} (s. $\text{XIII}^{1/2}$), Paris, Bibliothèque nationale de France, lat. 16208, fols. 5^{r}–12^{v} (s. XII^{ex}). See Mercier 1987: 101; Pedersen (Fritz) 2002: i. 105, 166; iii. 755, 1211 (CE40); iv. 1308 (EC), and p. 178 in this volume.

[9] MS Darmstadt, Universitäts- und Landesbibliothek, 765, fol. 215^{vb}.

[10] *Ezic Elkaurezmi*, c. 2 (ed. Suter 1914: 3).

[11] For this translation, see Neugebauer 1962: 133–234; Casulleras 1996.

[12] For this almanac, see Millás Vallicrosa 1943–1950: 72–237; Samsó 2020: 880–883.

[13] See MS London, British Library, Royal 7.F.VIII, fols. 180^{r}–191^{v} (s. $\text{XIII}^{2/2}$), where the almanac appears alongside lunar tables constructed in 1158. There are also notes for an epoch of 1151. For another copy of this original translation, which was revised by John of Pavia in 1239, see MS Erfurt, Universitätsbibliothek, Dep. Erf. CA 8° 81, fols. 1^{r}–23^{v} (s. $\text{XIII}^{2/2}$).

[14] See Ginzel 1906–1914: i. 258–260.

When it came to converting between Islamic lunar years and years of the Julian calendar, Robert could have found the pertinent computational rules in a number of sources, including the different Latin canons to the Toledan Tables.[16] The basic algorithm for converting any number of Christian years (C) into the equivalent number Islamic years (I), as given in *Lc2* (ll. 166–172), may be re-formulated as follows:

$$I = C \times 365\tfrac{1}{4} \times \tfrac{30}{10631}$$

The goal of this calculation is to yield complete numbers of days. Where smaller fractions arise, they are ignored unless they exceed one-half of a day, in which case they are counted as a full day (ll. 204–207). The algorithm for the reverse operation of converting Islamic into Christian years (ll. 173–178) may be written as:

$$C = I \times 354\tfrac{11}{30} \times \tfrac{4}{1461}$$

Robert illustrates the latter by applying it to $I = 3$, which in the first step yields 1063 1/10 days. The 1063 complete days are brought forward and multiplied by 4 to obtain 4252 quarter-days (ll. 179–184). If these are divided by 1461, one obtains 2 Julian (or solar) years with a remainder of 1330 quarter-days = 332 ½ days. According to Robert, this remainder amounts to 10 months and 29 days (ll. 184–186). His statement makes sense if one rounds 332 ½ days to 333 days and takes "10 months" (l. 185: *menses X*) to mean the length of the first ten months of the ordinary Julian year (January to October), which is 304 days (304 + 29 = 333).

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[15] *Collatio Compoti Romani et Arabici*, § 7 (ed. Nothaft 2015: 203).

[16] Ca36, 39 (ed. Pedersen [Fritz] 2002: i. 230); Cb15–16a, 21, 48 (ed. Pedersen [Fritz] 2002: ii. 386, 388, 400–402); John of Spain (or Seville), *Sententie de diversis libris excerpte* (ed. Millás Vallicrosa 1936: 461–465). See also Nothaft 2014: 43–44.

Prior to presenting the two algorithms just summarized, Robert offers a simplified variant for the conversion of Christian into Islamic years, which is based on only one type of fraction, namely, the quarter-days of the Julian year (ll. 157–165):

$$I = C\frac{1461}{1416}$$

It is not fully reliable owing to the fact that the 11/30 of a day added to each Islamic lunar year is here effectively omitted from the calculation.

*Lc*3

So far, Robert has merely shown how to convert full numbers of years in one calendar into the equivalent number of years and days of the other calendar. To be able to convert between specific dates in either calendar, it was necessary to know the difference that separated the epochs (i.e., the initial dates) of their respective eras. Robert begins *Lc*3 by illustrating this point with the simple example of the Christian era (epoch: 1 January AD 1) and the Spanish era (epoch: 1 January 38 BC), which differed by a round 38 Julian years (ll. 219–224).[17] Things were more complicated when it came to the relationship between the Christian era and the Hijri era, the epochs of which were separated by 621 Julian years and 195 days. To summarize the pertinent instructions Robert provides in *Lc*3 (ll. 233–253), the first of the two algorithms presented in *Lc*2 may be modified and re-written as:

$$I = ((C - 621)\frac{1461}{4} - 195) \times \frac{30}{10631}$$

Whatever remainder results from this operation will be converted into days, which are to be grouped into alternating months 30 and 29 days (ll. 253–256), as are used in the Islamic calendar.

*Lc*4

Robert next inserts a brief chapter offering general instructions on how to enter tables for planetary mean motions with a given number of years of the relevant calendrical system. It sets the stage for *Lc*6–7, which are geared specifically towards working with his Tables of London. The main difficulty he addresses in *Lc*4 is that some tables may count their collected years from a different date than the epoch of the era that is normally associated with their calendar. This was indeed the case in the two sets included in his *Liber canonum*, neither of which began its count of years in AD 1. In the case of the Toledan Tables included in the first part, the *radix* was placed at 1 January 1149, making it necessary to subtract 1148 from the completed years AD before entering the tables. The Tables of London began on 1 March of the following year, necessitating a subtraction of 1149 years (ll. 270–279).

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[17] On the Spanish era, see Ginzel 1906–1914: iii. 175–178; Vives 1938; Neugebauer 1981.

*Lc*5

Robert interrupts his account of how to enter the mean-motion tables by showing how to determine the difference in geographic longitude between two places, which is a basic precondition to adjusting a given set of tables to a different meridian. He here relies on the most common medieval solution to the 'longitude problem', which is based on the observed—or, rather, observed and computed—times of an eclipse.[18] Among the first texts to teach this method to a Latin audience was a treatise on the uses of the astrolabe by Ibn al-Ṣaffār (d. 1035), which was translated into Latin twice in the first half of the twelfth century, by John of Seville and Plato of Tivoli.[19] It also worth noting that John's translation was later re-fashioned into the very widely used *Practica astrolabii* attributed to Māshā'allāh.[20] Ibn al-Ṣaffār's treatise is the probable source behind the pertinent chapter in Robert's own *Liber de officio astrolabii* (see p. 194), which offered the following account of how to determine local longitude.

> Duorum vero locorum longitudinum distantia quantitas est graduum circuli equinoctialis quibus meridies loci unius a meridie alterius distare

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[18] On the background, see Wright 1923: 80–85; Gautier Dalché 1998: 196–202; 2000: 410–424.

[19] Ibn al-Ṣaffār, *On the Uses of the Astrolabe*, trans. John of Seville, c. 26 (ed. Millás Vallicrosa 1942: 275); Ibn al-Ṣaffār, *On the Uses of the Astrolabe*, trans. Plato of Tivoli, c. 28 (ed. Lorch, Brey, Kirschner, and Schöner 1994: 160). See Kunitzsch 1982: 486–487. For other accounts of the eclipse method available in Latin in Robert's time, see Adelard of Bath, *Libellus de opere astrolapsus* (ed. Dickey 1982: 193–196); al-Battānī, *Opus astronomicum*, c. 6 (ed. Nallino 1899–1907: i. 19–20); Petrus Alfonsi, *Dialogus*, tit. 1.64 (ed. and trans. Cardelle de Hartmann, Senekovic, Ziegler, and Stotz 2018: 36–37).

[20] pseudo-Māshā'allāh, *Practica*, c. 26 (ed. Gunther 1929: 224–225). See Kunitzsch 1981: 48–56; 1982: 501–502.

> probatur. Hec autem distantia accipitur sic. Eclipsis ergo solaris seu lunaris initio fineque in utriusque regionibus observato quot horas equinoctiales a meridie proxima ante eclipsim ad initium eclipsis vel eius finem in utraque regione inveneris diligenter observa. Deinde cuiuscumque regionis earum hore pauciores extiterint ad horas alterius regionis [*ms.* regiones] minuantur. Quodque superfuerit in 15 ducito fientque gradus qui videlicet cum suis partibus, si fuerint, distantiam longitudinum ipsorum locorum indicabunt. Si igitur unius loci longitudo nota alteriusque tibi longitudo ignota fuerit, si locus cuius longitudinem ignoras loco alteri orientalis extiterit, gradus distantie eorum longitudinum longitudini [*ms.* latitudini] note adicias; si vero occidentalis, eos eidem demas; sicque per notam unius loci longitudinem alterius loci longitudinem invenire poteris.[21]
>
> The distance in longitude between two places is the number of degrees of the equinoctial circle by which the meridian of one place is shown to be removed from the meridian of the other. This distance, however, is determined as follows. Having observed the beginning and end of a solar or lunar eclipse in both regions, you must carefully take note of how many equinoctial hours you find in either region between the noon immediately before the eclipse and the beginning of the eclipse or its end. Whichever of these regions has fewer hours, one must afterwards subtract them from the hours of the other region. Multiply what is left by 15 and they will become degrees, which together with their parts, if there are any, will reveal the distance in longitude between these places. If it is the case, then, that the longitude of one place is known and the longitude of the other is unknown to you, you must add the degrees of the distance between their longitudes to the known longitude, provided the place whose longitude you are ignorant of is to the east of the other one; but if it is to the west, you will subtract them from it; and this way you will be able to use the known longitude of one place to find the longitude of the other place.

The instructions at the beginning of *Lc*5 (ll. 298–308) are stylistically and doctrinally very similar to those in the passage just cited. Robert here presupposes that the reader already understands the concept of longitudinal difference, which the astrolabe treatise defines as the distance between meridians measured in equatorial degrees. At the same time, *Lc*5 adds elements not found in the other text. For one thing, Robert goes into more detail by making explicit how to infer the relative position of two places along an east-west direction from the known eclipse times (ll. 309–315). To this he joins a discussion of the equivalences and conversions between minutes of time and equatorial degrees and minutes (ll. 316–329).

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[21] MS Milano, Biblioteca Ambrosiana, H 109 sup., fol. 15^{r-v} (c. 25).

In both texts, Robert describes the eclipse method as if it required observing the same eclipse in two different regions.[22] A more in-depth and realistic account might have noted that the easiest way to put this method into practice was to compare the observed eclipse time at one's local meridian with a *computed* time, that is, the time of an eclipse predicted by some set of astronomical tables for a known meridian of reference. Robert and his contemporaries could find such an account in Raymond of Marseilles's *Liber cursuum planetarum* (1141), which accompanied the Tables of Marseilles, the earliest known adaptation of a set of Islamic mean-motion tables to a meridian in Christian Europe. According to Raymond, the difference in time that separated Marseilles and Toledo was 1;6h, which implied a longitudinal gap of 16;30°.[23] (The actual distance between the two cities is *c.* 9;24°.) To those who desired to know the longitude of their own city with respect to that of Marseilles, he recommended to

(a) compute the time of the beginning or end of an eclipse;
(b) convert the computed time from equinoctial hours into seasonal hours;
(c) observe the beginning or end of the same eclipse with a reliable instrument and compare the time thus found with the time previously computed;
(d) convert the observed time difference into equinoctial hours.[24]

As seen, Raymond's instructions contained some additional steps that took into account that observed eclipse times would have typically been measured and recorded in seasonal hours, whereas astronomical tables operated with equinoctial hours. The necessary conversion between hour-types is also addressed in Robert's *Lc*, albeit later in a chapter devoted to syzygy times (*Lc*24). An additional issue that both Raymond and Robert ignored in their respective presentations of the eclipse method was the equation of time, which would have been required to convert a predicted time into apparent solar time or, conversely, an observed time into mean solar time. The only Latin text from the mid-twelfth century to pay attention to this important nuance is the *Liber de rationibus tabularum* composed in 1154 by Abraham Ibn Ezra, who had previously used a solar eclipse and his Tables of Pisa to determine the longitude of Angers.[25]

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[22] The same is true of the account in Ibn al-Ṣaffār's astrolabe treatise. See n. 19 above.

[23] Raymond of Marseilles, *Liber cursuum planetarum* 2.1b, 3a (ed. Alverny, Burnett, and Poulle 2009: 200, 204).

[24] Raymond of Marseilles, *Liber cursuum planetarum* 2.3b–f (ed. Alverny, Burnett, and Poulle 2009: 204). See also ibid. 1.38 (ed. Alverny, Burnett, and Poulle 2009: 154–156).

In manuscript *A*, the passage on the conversion of minutes of time into degrees and minutes of longitude (ll. 316–331) is followed by a brief account of an alternative method of measuring longitudinal differences, which is here attributed to the "Toledan doctors" (*Toleti doctores*). We are told to measure the time when a particular degree of the zodiac or a particular fixed star culminates at one meridian and then do the same for another.[26] This method is rather curious for being utterly impractical in a medieval context. Eclipses could be used to measure longitude differences precisely because they were simultaneous events with different local times at different meridians. The situation for stellar culminations, by contrast, was almost the exact reverse. They shared almost identical local times but were non-simultaneous events with respect to some universal time standard. To establish a time difference between them would accordingly have required a method of time-measurement that was directly tied to such a universal standard. Given the flawed nature of the proposal and the fact that this passage is not attested in *S*, I have decided to treat it as extraneous to Robert's original text and, therefore, to relegate it to the apparatus of the above edition.

Robert concludes *Lc*5 with a tabular list of the geographic coordinates—longitudes and latitudes—of 21 cities and regions in Europe, North Africa, and the Near East.[27] In its original state, this list appears to have displayed degrees as well as minutes of arc, although the columns for minutes remain empty in the extant copies (*AS*). The only exception is Toledo in manuscript *S*, where the longitude is given as 28;30°. This is the exact value implicit in the canons to the Toledan Tables, which place Toledo 61;30° west of Ujjain (*Arin*), the Indian city that had provided the meridian of reference for the *Sindhind Zīj* of al-Khwārizmī.[28] In Andalusian astronomy, this city was commonly considered the geographic centre of an oikumene that extended over 180°, which suggested placing the western prime meridian precisely 90° west of Ujjain. If Toledo is located 61;30° west of Ujjain, its longitude with respect to this western meridian (also known as the 'meridian of water') will on this basis turn out to be 28;30°, whereas Ptolemy had placed Toledo 11° from his prime meridian through the Fortunate Islands.[29]

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[25] Abraham Ibn Ezra, *Liber de rationibus tabularum* (ed. Millás Vallicrosa 1947: 88, ll. 12–30).

[26] *A*, fol. 25^{rb}: "Sed et si absque eclipsium prenotatione iuxta Toleti doctores id ipsum tractare volueris, ipsam horam et eius partem qua quilibet gradus signiferi seu quelibet stella fixa in duabus regionibus, note scilicet et ignote longitudinis, celum mediaverit observabis ipsamque horarum utriusque regionis differentiam diligenti ratione notabis. Quibus annotatis prout iuxta communem astrologorum sententiam predocuimus cetera omnia pertractentur."

[27] Extracts from this list are printed in Mercier (1991: 27) and Pedersen (Fritz) 2002: iv. 1517–1518 (MA13), who suggest modern identifications for the place names in question.

The conflict between these two conventions for reckoning western longitudes was recognized by a corrector whose hand is visible in *A*. He made interlinear additions to Robert's list of coordinates that provided alternative longitudes for several of the Iberian cities. In the case of Córdoba, which Robert's table puts at 28°, he noted an alternative value of 9°, which is close to Ptolemy's 9;20°. In the remaining cases, the alternative value is always lower by 17°, which comes closer to the 17;30° that separate the two prime meridians (28;30° – 11° = 17;30°).

A comparison of the longitudes and latitudes in Robert's list with those recorded in Edward and Mary Helen Kennedy's catalogue of *Geographical Coordinates of Localities from Islamic Sources* (1987) reveals no obvious dependence on any known source. In fact, Robert's coordinates often differ significantly and in sometimes puzzling ways from the values found in Islamic lists of this nature. In what follows, I shall underscore this point by commenting briefly on each individual location in Robert's list, here sorted alphabetically.

Africa (36°, 35°). The list of coordinates in al-Battānī's *zīj* agrees with our list in giving Africa a longitude of 36° but has a lower latitude of 31°.[30] The latitude of 35° in our list does not seem to be attested elsewhere and may be the result of some scribal corruption.

Alexandria (45°, 30°). Alexandria, Egypt. The lowest value commonly given for Alexandria's longitude in Islamic sources is 51;20°. The 45° given here are therefore likely to be the result of an error. Latitudes between 30° and 31° are common.

Almaria (30°, 36°). Almería, Spain. Islamic sources give the longitude of Almería as 28° or lower. Latitudes between 36° and 36;30° are common.

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[28] Ca82, 90; Cb133 (ed. and trans. Pedersen [Fritz] 2002: i. 250–251, 254–255; ii. 430–431); cf. *Ezich Elkaurezmi*, trans. Adelard of Bath (ed. Suter 1914: 1).

[29] On the background, see Comes 1992–1994; 2000: 124–128; Samsó 2020: 703–708.

[30] Nallino 1899–1907: ii. 34.

Anglia (18°, 52°). England. A value of 52° for local latitudes had been known in England since the late eleventh century, if not earlier.[31] The longitude of 18° is consistent with several British localities recorded in Ptolemy's *Geography*, such as Rigodunum (Castleshaw Roman fort), Corinium (Cirencester), and Ratae (Leicester).[32] In twelfth-century Latin sources, the most prominent longitude for England instead appears to be 19°, as applied to Winchester and London.[33] The known examples include the Tables of London in *L*, where this longitude is cited in a heading to the solar mean-motion tables (*L*, fol. 7^{v}). As was noted above (p. 211), a longitude of 19° for London also follows from the differences in radices between the Tables of London and the Tables of Pisa, provided Pisa is placed at a longitude of 33°. Implicit evidence of an assumed value of 18° is nevertheless provided by a gloss that was added to the mean-motion tables for Mars (*L*, fol. 24^{v}), which indicates that the radices will have to be lowered by 0;0,53° to adjust them to the meridian of Toledo. The same mean-motion tables show 0;0,53° as the entry corresponding to a time interval of 0;42h, which would be equivalent to a longitude difference of 10;30°. This happens to be consistent with Robert's list at the end of *Lc*5, which gives the respective longitudes of 'England' and Toledo as 18° and 28;30°. A further witness to a difference of 10;30° between these two places is the copy of the Tables of Pisa in *P*, which incorporates *Lc*8's tables for the solar apogee (*P*, fol. 4^{v}). A note accompanying them gives the longitude of London as 29° but also states that the difference in solar motion between London and Toledo is 0;1,43°. Once again, the difference in motion corresponds to a time difference of 0;42h (according to the London mean-motion tables) and a longitude difference of 10;30°.

Babilonia (45°, 30°). Islamic sources tend to situate Babylon between 69° and 80° longitude and between 32° and 35° latitude. The longitude of 45° cited in our list is clearly mistaken, seeing as it would place Babylon on the same meridian as Alexandria.

Aracca (73°, 38°). Ar-Raqqah, Syria. The longitude is consistent with the value of 73;15° commonly found in Islamic lists. The latter are nearly unanimous in giving ar-Raqqah's latitude as 36°, so the 38° in our list may be due to a scribal mistake.

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[31] Walcher of Malvern, *De lunationibus* 3.4 (ed. Nothaft 2017: 110). See also MS Oxford, Bodleian Library, Auct. F.1.9, fols. 83^{va}–84^{ra} (s. $\text{XII}^{2/4}$), cited in Nothaft 2017: 234–235 (n. 48).

[32] Ptolemy, *Geography*, 2.3.16, 20, 25 (ed. and trans. Stückelberger and Graßhoff 2006: i. 154–157).

[33] See North 2002 and my remarks in Sela, Steel, Nothaft, Juste, and Burnett 2020: 212–213.

Baldac (81°, 33°). The values in our list are in rough agreement with the ones most Islamic sources provide for the coordinates of Baghdad, with longitudes between 80° and 81° and latitudes between 33° and 34°. It therefore appears to be the city intended.

Bugea (32°, 34°). Mercier and Pedersen both identified this city with Béjaïa, Algeria.[34] Manuscript *A* cites an alternative latitude of 30°.

Cesar Augusta (29°, 42°). Saragossa, Spain. One of the longitude values attested in Islamic sources is 29;55°. The latitudes lie between 41;30° and 42;30°.

Corduba (28°, 38°). Córdova, Spain. Manuscript *A* has 35° for the latitude rather than 38°. It is difficult to decide between these variants, as both have support from Islamic lists. The longitudes attested in these lists suggest that 28° may be an error for 18° or 27°.

Denia (28°, 39°). Dénia, Spain. Latitudes between 39° and 39;10° are common in Islamic lists. The longitude of 28° is not attested elsewhere.

Hispalis (27°; 38°). Seville, Spain. Manuscript *A* gives an alternative latitude of 35°. None of these values agree closely with known Islamic lists.

Ierusalem (55°, 33°). The latitude of 33° for Jerusalem is common. The lowest longitude attested in Islamic sources is 56°.

Marroca (17°, 30°). The precise identification of this place is uncertain, but could be Marrakesh, Morocco. There is no close match with the coordinates attested in Islamic sources.

Miscene (35°, 36°). Messina, Italy. Manuscript *A* has an alternative longitude of 32°. The longitude of 35° for Messina receives support from some Islamic lists, although the latitudes in these sources are 38;15° or higher.

Osca (26°, 40°). Identification uncertain.

Pannonia (33°, 38°). Manuscript *A* has an alternative latitude of 35°. Rather than referring to the ancient region of Pannonia, *Pannonia* here may be an error for *Panormum*, i.e., Palermo. Islamic sources attribute to Palermo longitudes between 35° and 45° and latitudes between 36° and 37°.

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[34] Mercier 1991: 27; Pedersen (Fritz) 2002: iv. 1518.

Pisa (33°, 45°). Pisa, Italy. The longitude of Pisa is stated as 33° in Abraham Ibn Ezra's *Liber de rationibus tabularum* (LRT, p. 87, ll. 20–21) and the related *Tractatus magistri Habrahe de tabulis planetarum* (*L*, fol. 56^{va}). Longitudes between 33° and 34° are also commonly found in Islamic sources, yet none has the latitude of 45° given in our list.

Roma (35°, 41°). Rome, Italy. The values are consistent with the widely used pair of 35;25° (long.), 41;50° (lat.), which is also attested in the coordinate list included in the Toledan Tables.[35]

Sicilia (35°, 35°). A round longitude of 35° is assigned to Sicily in some Islamic sources, notably Ibn Yunus and al-Biruni,[36] whereas recorded latitudes tend to be 36° or higher.

Toletum (28;30°, 40°). Toledo, Spain. The longitude agrees with the canons to the Toledan Tables (see p. 307). The latitude of 40° is widely attested in Islamic lists and in the Toledan Tables themselves.[37]

Tripolis Barba (39°, 30°). Tripoli, Libya. There is no close match with the coordinates attested in Islamic sources.

Valencia (29°, 39°). Valencia, Spain. There is no close match with the coordinates attested in Islamic sources.

*Lc*6

After the preliminary remarks in *Lc*4, Robert now explains in more detail how to operate with the specific mean-motion tables for London that originally came with the second part of his *Liber canonum*. The first step is to subtract 1149 years from the completed years AD, provided the targeted date falls on or after the *radix* of 1 March 1150 (ll. 370–372, 381–383). The remainder is divided by 20 to determine the numbers with which to enter the tables for collected and expanded (or "residual") years (ll. 372–374, 383–392). Robert points out that the values shown in these and the other sub-tables must be added together while observing the "natural arrangement" (*naturalis dispositio*) of joining together units of the same type—signs to signs, degrees to degrees etc. (ll. 377, 389–392). To facilitate these additions, he recommends writing the entries from different tables below each other on an *albiolus*, meaning a blank sheet of parchment (l. 387). In giving these instructions, he twice refers to an earlier discussion of the same topic (ll. 377, 387–388). Since there is no such passage in the preceding chapters of *Lc*, it presumably appeared in the missing first part of the *Liber canonum* in an analogous discussion of using the tables for the meridian of Toledo.

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[35] Pedersen (Fritz) 2002: iv. 1513 (MA11).

[36] See Kennedy and Kennedy 1987: 321.

[37] Pedersen (Fritz) 2002: iv. 1512 (MA11).

Capitalizing on the information provided in *Lc*5, Robert adds an explanation of how to adjust the mean longitudes obtained from the Tables of London to other meridians (ll. 415–422). Depending on whether the intended location is west or east of London, one will have to add or subtract the amount of mean motion equivalent to the *differentia longitudinum* (ll. 417–418). What is meant here is not the actual difference in geographic longitude, but rather its time-equivalent, which can be converted into degrees of planetary motion using the same mean-motion tables.

*Lc*7

The rule given in *Lc*6 is restricted to dates that fall on or after the initial date or *radix* used in the Tables of London, which is 1 March 1150. To find the mean longitudes for earlier dates, one will first have to create the appropriate collected-year entry by subtracting multiples of the mean-motion increment for 20 years from the *radix* shown in the tables (ll. 432–438). In explaining the precise sequence of steps to be taken, Robert assumes that the reader will know the interval between the targeted past date and their own *annus praesens* but has not yet established an absolute date for the former. He therefore recommends subtracting the mentioned interval from the years of the Christian era that have been completed ahead of the *annus praesens*. Afterwards, the remainder is subtracted from the completed years contained in the initial *radix* to yield the number of years by which the targeted past date precedes the *radix* (ll. 425–432). Only at the end of this chapter are we reminded of a quicker way of getting to the same end result, which is to take the interval between the targeted past date and the *annus praesens* and subtract from it the time elapsed since the *radix* (ll. 465–469).

To elucidate the first version of the procedure, Robert uses the example of the (annular) solar eclipse of 21 May 1137, which according to him occurred “when roughly the eighth hour had passed,” hence indicating the ninth hour of the day (ll. 447–449).[38] The fact that he places the present year 33 years later, in AD 1170 (l. 443), has caused a certain degree of confusion among previous scholars. Mercier took it to imply that *Lc*1–8, which he considered to be a separate text from *Lc*9–25, was written around this year. He concluded from this dating that Robert of Chester was only responsible for the Tables of London, whereas the chapters in question were written by someone else at a later date.[39] It is important to note, however, that *Lc*7 nowhere states that AD 1170 is the actual *annus praesens* of the author writing these lines. Rather, the whole passage mentioning this year is clearly marked as an *exemplum* (l. 442) and ought to be read as a hypothetical.

*Lc*8

In Ptolemaic computational astronomy, the determination of the true longitude of the Sun or any of the five planets cannot proceed without prior knowledge of the longitude of the respective apogee, which is necessary to calculate the equation. In a sidereal frame of reference, as used by al-Khwārizmī’s *Sindhind Zīj* and Toledan Tables, these apogeal longitudes remain perpetually fixed, such that no further computation is required to obtain them. By contrast, the tropical reference frame relied upon in the Tables of London made it necessary to factor in the gradual displacement of the apsidal lines of the planets with respect to the vernal point, which was caused by precession. In the astronomical literature of the later Middle Ages, the most common term for ‘apogee’ is the loan word *aux*, which was derived from Arabic *awj* (أوج). Robert preferred to use *absis*, a choice that hearkened back to ancient Roman authors such as Pliny and Martianus Capella.[40] A more immediate influence in this regard may have been Robert’s contemporary Hugo Sanctelliensis, who used *absis* in his translation of a commentary on al-Khwārizmī’s original tables by Ibn al-Muthannā (see p. 203).

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[38] According to modern calculation, the eclipse in question began at *c.* 16:41h at the meridian of London. See the *Javascript Solar Eclipse Explorer* on the Nasa Eclipse Website: https://eclipse.gsfc.nasa.gov/JSEX/JSEX-index.html.

[39] Mercier 1987: 109 (with n. 63); 1991: 18. See also Pedersen (Fritz) 1990: 199, 211; Southern 1992: xlix.

[40] See Pliny, *Naturalis historia* 2.63–65 (ed. Rackham 1949: 210–212); Martianus Capella, *De nuptiis Philologiae et Mercurii* 8.884–886 (ed. Willis 1983: 335–336).

Robert begins *Lc*8 by distinguishing two different doctrines concerning the planetary apogees, depending on whether they are considered immobile or mobile (ll. 471–484). Although Robert does not identify any adherents to the former view, it seems likely that he believed it to be represented by the tables of al-Khwārizmī, which left the apogees in a fixed sidereal place and made no reference to precession. He may have taken the same view of the Toledan Tables contained in the first part of his *Liber canonum*. Even though the original Toledan Tables and their various derivations came with tables for the 'access and recess' of the eighth sphere, which could be used to compute the amount by which the apogees moved in a tropical reference frame,[41] it is possible that Robert's rendition omitted any such tables, as is indeed true of the Tables of Marseilles included in Raymond of Marseilles's *Liber cursuum planetarum* (see p. 217).

He closes out the chapter by asserting that those who consider the apogees immobile have their opinion "destroyed in accordance with al-Battānī" (l. 520: *iuxta Albatem annnullatur opinio*), which would seem to evince his support for al-Battānī's view that the apogees of the Sun and the five planets all undergo precession along with the fixed stars. Like other Islamic astronomers before him,[42] al-Battānī had modified Ptolemy's position according to which this motion only affected the planets, while the solar apogee remained tropically fixed. He also famously derived a much swifter rate of precession than that accepted by Ptolemy, 1°/66y as opposed to 1°/100y.[43]

Given the appeals to al-Battānī in this chapter as well as in *Lc*1, it is somewhat surprising to see that Robert's value for the rate of precession is similar, but not identical. In the *Ṣābiʾ Zīj*, the aforementioned rate of 1°/66y is taken as an exact value. The precession tables in this work accordingly operate with an annual precession increment of 1°/66y = 0;0,54,32,43…°/y, such that the precession in 20 years is shown as 0;18,11°.[44] In *Lc*8, by contrast, the exact parameter is 0;0,54°/y, which sums up to 0;18° in 20 years and to 1° in 66;40 years, which is 66 years and 8 months (l. 487). The fixed stars will accordingly go full circle in exactly 24,000 years, as Roberts himself states (ll. 477–480). This 24,000-year period makes an appearance in Abraham bar Ḥiyya's Hebrew treatise *On the Shape of the World*, which dates from 1132.[45] It is also mentioned in Abraham Ibn Ezra's Latin *Liber de rationibus tabularum* (LRT, p. 94, l. 20), although this treatise was written in 1154 and hence probably too late to have influenced Robert of Chester's *Liber canonum*. If he did not take his 0;0,54°/y from any other source, an alternative explanation would be that he simplified the 0;0,54,32,43…°/y implicit in al-Battānī's precession table by ignoring fractions smaller than seconds of arc.

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[41] Pedersen (Fritz) 2002: iv.1542–1566. See also p. 146 in part I of this volume.

[42] See Morelon 1996: 26–31.

[43] al-Battānī, *Opus astronomicum*, c. 51 (ed. Nallino 1899–1907: i. 124–125). On the history of this parameter, which extends back beyond al-Battānī, see Kurtik 1990; Mozaffari 2016: 303–305. The first Latin author to mention the precession rate of 1°/66y appears to be Hermann of Carinthia in 1143. See *De essentiis*, bk. 1, 66vH (ed. Burnett 1982: 140, l. 2). See also Stephen of Pisa, *Liber Mamonis* 3.2, 4.2 [§§ 196–198, 286] (ed. Grupe 2019: 332–333), who mentions a precession rate of 1°/106y. This otherwise unattested value could be a corruption of al-Battānī's 1°/66y (as suggested by Grupe 2019: 75) or the result of a confusion with his length of the tropical year. The latter is 365;14,26d, which implies a shift of the equinoxes with respect to the Julian year of approximately 1d/106y.

[44] Nallino 1899–1907: ii. 107. See also the Latin rendition in MSS Cambridge, Fitzwilliam

In contrast to al-Battānī's precession tables, which contained no radices but simply listed the precessional increment as a function of time, the tables appended to *Lc*8 are clearly designated as serving the motion of the solar apogee. The first entry in the collected-year table accordingly shows the longitude of the solar apogee on 1 March 1150, the initial epoch of the Tables of London (ll. 9–10, 105–107). As Robert takes care to point out (ll. 506–520), it is nevertheless possible to apply his tables to the other planetary apogees as well as the fixed stars, owing to the fact that they all partake in the same precessional motion. The tables in question are transmitted in all four extant witnesses to *Lc*8 (AC_2SS_2), albeit with some noticeable imperfections. Among these are incorrectly transcribed numbers as well as omissions of certain entries or entire columns. Further renditions of Robert's tables for the solar apogee have been preserved among the Tables of London in *L* and *T*. In another manuscript, *P* (fol. 4ᵛ), they appear in the context of a condensed copy of the original Tables of Pisa, with their extraneous origin noted in the heading (*Absis solis in annis domini collectis ad meridiem Londoniarum*).

Robert's sub-table for collected years originally had 27 lines, running from the *radix* to 529 collected years (= 1669 completed years of the Christian era). In C_2, the table extends for another five lines to 629 collected years. This rendition also comes with an additional column to the very right of the page, which shows the current year AD for each line of the collected-year table (from 1150 to 1770). The scribe of *P* curtailed the collected-year table to make it fit the format of his copy of the Tables of Pisa. As a result, it has only seven entries, which are assigned to the completed years 1169 to 1289. This is misleading insofar as

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Museum, McClean 165, fol. 79ᵛ (s. XII$^{4/4}$); Cambridge, Gonville & Caius College, 456/394, p. 139 (s. XIII^{in}).

[45] Abraham bar Ḥiyya, *Forma de la tierra* (trans. Millás Vallicrosa 1956: 119).

the first entry in Robert's table was originally meant to be valid for 1149 completed years. A corrective is provided by a note added to the same page, which indicates the correct *radix* to be used for the solar apogee (*P*, fol. 4$^{\text{v}}$: *Radix huius tabule absidis Solis fuit* M.C.XL.VIIII).

It would appear that the lines in Robert's collected-year table were originally intended to increase uniformly by 0;18° on the basis of an annual precession of 0;0,54°. The only deviation from this rule in the extant copies is the increase between the first and second entry. In ASS_2 as well as in *LPT*, this increase is 0;19°, from 2s 26;20,18 to 2s 26;39,18°. Only C_2 shows the apogeal position at *radix* as 2s 26;21,18°, consistent with a uniform increase by 0;18°.[46] In S_2, the column for seconds of arc misses most of its entries.

The key to the sub-table for expanded years is the already mentioned annual precession of 0;0,54°. This is indeed the entry for year 1 in all witnesses except C_2, in which the column for seconds of arc is displaced downwards by one line. The entries in this column were meant to increase uniformly by 0;0,54° per line, regardless of whether the years are common or bissextile. Despite the displacement just mentioned, C_2 is the only witness in which this increase is applied consistently. In the remaining witnesses, the column for seconds of arc shows entries that are 10 seconds too high for years 4 to 19.

The sub-table for months was built from a steady increase of 0;0,4,30°, which is precisely 1/12th of the annual rate 0;0,54° or 30 times the daily rate of 0;0,0,9°. As with the expanded-year table, this uniform increase is at odds with the Julian calendar, where the months have unequal lengths. Things look different in C_2, which was re-computed on the basis of the diverging values in its sub-table for days (see below). Manuscripts A and *P* both omit the column for thirds of arc.

The entries in the sub-table for days were originally supposed to rise uniformly by 0;0,0,9°, which is 1/30th of the monthly increment 0;0,4,30° used in the previous table. For reasons that are unclear, a different principle was observed in C_2, where the entries occasionally rise by 0;0,0,8°, making the final entry 0;0,4,27° rather than 0;0,4,30° (miscopied as 0;0,4,21° in *A* and 0;0,4,31° in SS_2). The alternative values in this sub-table account for most of the entries in C_2's sub-table for months, which increase by 0;0,4,27° for 30-day months and by 0;0,4,36° for 31-day months. In *L* and *T*, this sub-table only displays seconds of arc. The same is true of *P*, which reduces this sub-table to five entries for 7, 15, 20, 27, and 30 days. Both this table and the one for months are limited to one just column for seconds of arc, here erroneously labelled *puncta* ('minutes').

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[46] The value of 2s 26;21,18° is confirmed in a gloss added to a copy of Toledan canons 'Ca' in *S*, fol. 32$^{\text{r}}$ (bottom margin), which clearly describes the precession table in *Lc*8, attributing it to al-Battānī: "Sequitur de abside Solis. Scito quod aux ecentrici Solis movetur ab occidente versus orientem secundum Ptholomeum in 100 annis uno gradu, sed Albategni dicit quod in 20 annis transit 18 minuta firmamenti. Unde fecit tabulas de abside et docuit quantum transeat aux in diebus, mensibus et annis. Consideravit etiam quod anno domini 1149 fuit absis Solis 2.26.21.18 secunda ideoque notavit hoc in prima linea annorum collectorum. Et crescit tabula per 20 annos. Si ergo velis formare secundam lineam a prima, adde motum augis in 20 annis, scilicet 18 minuta, notato in prima linea, et habebis secundam. […] Tabulam annorum sic formabis: duplicabis primam lineam et habebis secundam. […] Inveniatur ergo motus absidis ut medius motus Solis omnimodo. Absis Solis dicitur arcus interiacens primum gradum Arietis et augem Solis. Crescit autem paulatim absis propter motum augis per motum 8 spere. Scribiturque in tabula de abside quantum movetur in die, quantum in mense, quantum in anno."

The final sub-table, for hours, only appears in the witnesses to *Lc*8 and is accordingly absent from *LPT*. It was based on an hourly rate of 0;0,0,0,22,30°, which is 1/24th of the 0;0,0,9° used in the previous sub-table. In ASS_2, the entries in the column for fourths of arc are mostly too high by 1 in lines 3–18, 22–23 and too high by 2 in lines 19–21. They also agree in giving the entry for 9 hours as 0;0,0,3,26,30° rather than 0;0,0,3,22,30°. In the column for thirds of arc, they show "0" in all lines that would normally be expected to repeat the previous entry. The copy in C_2 exhibits none of these defects.

*Lc*9–13

As has previously been noted (p. 213), the equation tables that accompany the London tables in *L* and *T* are practically the same as those included in the Toledan Tables, which in turn can trace their origin back to al-Battānī's *Ṣābiʾ Zīj*. Since the lost first part of the *Liber canonum* was itself concerned with an adaptation of the Toledan Tables, it may be conjectured that Robert used a single set of equation tables to serve both parts of his work. The 'Toledan' equation tables follow al-Battānī in reckoning with a maximum equation of 1;59,10° for the Sun and with a maximum equation of anomaly of 41;9° for Mars. By contrast, the equation tables associated with the Tables of Pisa lowered the first value to 1;59,8° while raising the second to 41;10°.[47] Another obvious point of divergence between these two sets concerns the format of the table for the solar equation. The 'Pisan' version incorporates an additional column for the solar declination, which is not the case in the 'Toledan' format imitated by the Tables of London. Rather, the solar declination was the subject of a separate table, the use of which is explained in *Lc*10. This gives us grounds to suppose that Robert's original work included a declination table of the 'Toledan' type, despite the fact that no such table appears in *L* or *T*.[48]

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[47] For these equation tables, see *V*, fols. 2^{v}, 4^{r-v}, 8^{v}–12^{v}, 16^{r}–20^{r}, 22^{v}–25^{r}, 26^{v}–29^{r}, 30^{v}–33^{r}, 34^{v}–37^{r}, 38^{v}–41^{r}; *K*, fols. 183^{v}–190^{v}. See also pp. 11–13 in part 1 of this volume.

Given Robert's reliance on Toledan-type equation tables, it should come as no surprise that his rules for finding the true longitudes of the Sun (*Lc*9), Moon (*Lc*11), and five planets (*Lc*19–20) as well as the lunar latitude (*Lc*12–13) are all very similar to those found in the preserved canons to the Toledan Tables. This is true especially with respect to the most widespread of these canons ('Cb'), whose technical vocabulary overlaps to a large degree with that in Robert's *Liber canonum* (see pp. 202–203).[49] *Lc*13 (ll. 720–724) describes the Moon's motion in latitude in a way that is reminiscent of the canon on the solar declination in one of the known recensions of Adelard of Bath's translation of the *Sindhind Zīj* of al-Khwārizmī.[50] As in the latter text, Robert distinguishes four different phases of latitudinal motional, depending on whether the celestial body in question was northern or southern, ascending or descending. He also replicates Adelard's use of *proclivis* and *declivis* to signify 'ascending' and 'descending'.

In manuscript *S*, *Lc*9 and 11 are both augmented by paragraphs that do not appear to be germane to the original text and may have originated as marginal glosses (see the Appendix below). In *Lc*9, the additional text explains how to extrapolate the time of the vernal equinox from the known true longitude on the day in question. The same issue is addressed again in *Lc*23, making it unlikely that Robert originally already commented on it in the context of *Lc*9. *S*'s addition to *Lc*11 is a brief arithmetical remark to elucidate the application of the 'minutes of proportion' as a coefficient in computing the lunar equation of anomaly.

*Lc*14–15

A common element included in Islamic sets of astronomical tables, such as the *Sindhind Zīj* of al-Khwārizmī and the Toledan Tables, were tables for the conjunctions and oppositions of the Sun and Moon, which it made it easy to find not only the time of mean syzygy, but the corresponding mean longitudes of the luminaries, the lunar mean longitude in anomaly, and the argument of lunar latitude.[51] Once obtained, users could convert the mean solar and lunar longitudes into true ones and subsequently apply an algorithm to find the time interval between mean and true syzygy.[52]

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[48] See Ca44–46 and BA in Pedersen (Fritz) 2002: i. 232–234; iii. 946–966.

[49] Cb141a–151, 161–163 (ed. Pedersen [Fritz] 2002: ii. 434–440, 444).

[50] *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 15 (ed. Suter 1914: 13). The relevant recension is that known from MS Chartres, Bibliothèque municipale, 214, fols. 41^r–120^r (s. XII; destroyed in the Second World War), which is the recension Robert used for his revision (preserved in *M*).

Even though Robert would have been familiar with this type of table from revising Adelard of Bath's translation of al-Khwārizmī's *zīj*,[53] his account in *Lc*14 bypasses them completely. Instead, he avails himself of a simpler approach that goes back to the lost original version of the *Sindhind Zīj* and the associated canons. The pertinent 'Khwārizmīan' rules for computing syzygies were transferred into Latin as part of a commentary by Ibn al-Muthannā as well as, more fully, through one of the extant canons to the Toledan Tables ('Cc').[54] The influence of this source is manifest, moreover, in Raymond of Marseilles' *Liber cursuum planetarum* (1141), which pre-dates the *Liber canonum* by approximately a decade.[55]

The first step is to determine the true solar and lunar longitudes at the beginning of a day (i.e., at noon) on which the true conjunction or opposition is expected. According to al-Khwārizmī, this is the 29th day of the lunar month for conjunctions and the 14th day of the lunar month for oppositions. Robert adjusts this rule by also including the 28th and 13th day (ll. 731, 807), indicating that these lunar ages are correct according to the ecclesiastical lunar calendar, *iuxta compotum ecclesiasticum* (ll. 731–732). Practically the same expression (*iuxta ecclesiasticum compotum*) is used by Raymond of Marseilles, whose account of computing true syzygy exhibits striking similarities to that presented in *Lc*14–15.[56] The addition of the 28th and 13th day apparently reflects a growing contemporary awareness that the 19-year lunar cycle used by Latin computists had caused the ecclesiastical lunar calendar to be increasingly out of alignment with the actual phases of the Moon, with the result that the true conjunction could precede the calendrical beginning of the lunar month by two or even three days.[57]

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[51] See Tab. 69–72 in Suter 1914: 183–186; Neugebauer 1962: 108–115; Pedersen (Fritz) 2002: iv. 1327–1340 (GA); Chabás and Goldstein 2012: 139–144.

[52] On the problem of finding this time difference in medieval mathematical astronomy, see Chabás and Goldstein 1997; 2012: 144–150.

[53] See *M*, fols. 42^{v}–44^{r}.

[54] Ibn al-Muthannā, *Commentary on the Tables of al-Khwārizmī*, trans. Hugo Sanctelliensis (ed. Millás Vendrell 1963: 158–160); Cc135–140 (ed. Pedersen [Fritz] 2002: ii. 642–644; cf. Pedersen [Fritz] 1992: 51, 53).

[55] Raymond of Marseilles, *Liber cursuum planetarum* 2.20–25 (ed. Alverny, Burnett, and Poulle 2009: 226–230).

[56] Raymond of Marseilles, *Liber cursuum planetarum* 2.20a (ed. Alverny, Burnett, and Poulle 2009: 226): "Cum scire volueris utrum sol eclypsin pati debeat an non, invenies certa loca luminarium super eam diem in qua juxta ecclesiasticum compotum esse debet luna XXVIII vel XXVIIII, tunc scilicet cum fuerint cum capite vel cum cauda aut prope." Ibid. 2.22a (ed. Alverny, Burnett, and Poulle 2009: 228): "Cum vero scire volueris an luna eclypsin pati debeat necne, invenies loca luminarium super diem qua luna XIII vel XIIII fuerit." See also Ibn al-Muthannā, *Commentary on the Tables of al-Khwārizmī*, trans. Hugo

At the start of the chosen date, t, the true longitudes of the luminaries will normally be separated by a certain interval, η. Robert calls this interval *interstitium* (l. 736), a term already used in Adelard of Bath's translation of the Khwārizmīan canon for the aforementioned syzygy tables.[58] In the next step, the *interstitium* is used to approximate the true longitudes of the two luminaries at true syzygy. This is done on the basis of the rigid assumption that the Moon moves 13 times faster than the Sun. If this assumption holds true, the (negative or positive) difference between the true longitude at t and the true longitude at true syzygy will always be $(13/12)\eta$ for the Moon and $(1/12)\eta$ for the Sun (ll. 735–745).[59] This approach, if handled correctly, will always produce identical results for both luminaries, which is why Robert suggests that the procedure must be repeated if this outcome fails to present itself (l. 744).[60]

To find the time that remains until, or has elapsed since, true syzygy, η is divided by the difference between the hourly velocities of the two luminaries, or what Robert calls their *superamen* (l. 751). The result will be added or subtracted from the beginning of the date in question, depending on which

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Sanctelliensis (ed. Millás Vendrell 1963: 158). Ibn al-Muthannā here notes that the conjunction sometimes occurs on the 28th day and that oppositions fall between the 13th and 15th day.

[57] For a contemporary text addressing this situation with respect to eclipse dates, see *Collatio Compoti Romani et Arabici*, §§ 5, 7 (ed. Nothaft 2015: 203).

[58] *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 31 (ed. Suter 1914: 24). Raymond of Marseilles instead has *longitudo*. See *Liber cursuum planetarum* 2.20b (ed. Alverny, Burnett, and Poulle 2009: 226).

[59] This is the method described in *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 31 (ed. Suter 1914: 24); Cb174 (ed. Pedersen [Fritz] 2002: ii. 559); Cc245 (ed. Pedersen [Fritz] 2002: ii. 690); Raymond of Marseilles, *Liber cursuum planetarum* 2.20c–d (ed. Alverny, Burnett, and Poulle 2009: 226). Compare Cc140 (ed. Pedersen [Fritz] 2002: ii. 642–644); Ibn al-Muthannā, *Commentary on the Tables of al-Khwārizmī*, trans. Hugo Sanctelliensis (ed. Millás Vendrell 1963: 159–160), where the rule differs by working with the actual velocities of the luminaries.

[60] This is stated even more clearly in Raymond of Marseilles, *Liber cursuum planetarum* 2.20d–e (ed. Alverny, Burnett, and Poulle 2009: 226): "Si ergo post hec convenerint in eodem loco, certissime scias te bene fecisse. Quod si, ut diximus, non convenerint, te errasse cognoscas, et opus predictum replicabis usquequo luminaria conjuncta veracissime invenias."

luminary was ahead of the other at t (ll. 812–817).[61] Robert here relies on a table commonly found among the Toledan Tables, which shows the velocity of the Sun and Moon as function of the respective anomaly (ll. 755–802). It is included as part of *Lc*14 in all three witnesses (*ALS*). As with Robert's equation tables, the table for lunisolar velocities originated in the *zīj* of al-Battānī, who computed it on the assumption that the Sun and Moon are already at syzygy.[62] This assumption clashes with Robert's own computational rule, which uses the velocities at a moment when the two luminaries are still separated by η. In both al-Battānī's *zīj* and the Toledan Tables, the table for the hourly velocities was therefore accompanied by a small table of corrections designed to take into account η.[63] Robert ignored this table, as did his predecessor Raymond of Marseilles, leaving us guessing as to whether they had any awareness of it.[64] Another problem Robert shows no regard for is that the velocity of the Moon does not remain constant over the whole interval that separates the moment of the *interstitium* and the moment of true syzygy. In the Toledan canons, this problem is addressed by adding or subtracting (13/24)η to/from the lunar anomaly, which is a way of targeting the anomaly at the mid-point of the relevant time interval.[65]

*Lc*16–18

Knowing the time of true syzygy times is a precondition for determining the possibility and circumstances of eclipses, which is a topic Robert addresses succinctly over three chapters. In his initial remarks on the subject, he deploys the

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[61] This is the procedure described in Ibn al-Muthannā, *Commentary on the Tables of al-Khwārizmī*, trans. Hugo Sanctelliensis (ed. Millás Vendrell 1963: 158–159); Cc137–139 (ed. Pedersen [Fritz] 2002: ii. 642). A variant of this rule reckons with (13/12)η and thereby eliminates the solar velocity as a separate term (cf. p. 331 below). See *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 31 (ed. Suter 1914: 24); Cc241–242 (ed. Pedersen [Fritz] 2002: ii. 688). Both approaches are offered in Ca128–130, 149 (ed. Pedersen [Fritz] 2002: i. 274, 282); Raymond of Marseilles, *Liber cursuum planetarum* 2.21 (ed. Alverny, Burnett, and Poulle 2009: 226–228).

[62] See Nallino 1899–1907: ii. 88; Pedersen (Fritz) 2002: iv. 1409–1412 (JA11); Raymond of Marseilles, *Liber cursuum planetarum* 2.25 and Tab. 22 (ed. Alverny, Burnett, and Poulle 2009: 230, 339); Toomer 1968: 82–84; Chabás and Goldstein 2012: 95–96.

[63] Nallino 1899–1907: ii. 88; Pedersen (Fritz) 2002: iv. 1413–1414 (JA21); Toomer 1968: 85. See also Cb178 (Pedersen [Fritz] 2002: ii. 452).

[64] Raymond of Marseilles, *Liber cursuum planetarum* 2.25 (ed. Alverny, Burnett, and Poulle 2009: 230).

[65] Cb177 (ed. Pedersen [Fritz] 2002: ii. 452); Cc285 (ed. Pedersen [Fritz] 2002: ii. 708).

Arabic term for 'eclipse', الكسوف (*al-kusūf*), which he transliterates as *elkuszuf* (l. 820). This term had previously been introduced into Latin astronomy through Adelard of Bath's translation of the *Sindhind Zīj* of al-Khwārizmī, which Robert revised at some stage after or prior to writing the *Liber canonum* (see pp. 198–199). Indeed, the sole surviving manuscript of Robert's revision has precisely the same transliterated form we find in *Lc*15 (*elkuszuf*) as well as a deviant form produced by metathesis (*elszukuf*).[66]

As with Robert's chapters on true syzygy, the rules for computing diameters and eclipses in *Lc*16–18 are Khwārizmīan and have close parallels in the Toledan canons 'Cc' as well as in Ibn al-Muthannā's commentary on the *Sindhind Zīj*.[67] Their ultimate roots are found in Indian astronomical sources such as Brahmagupta's *Khaṇḍakhādyaka* (665).[68] In line with these sources, Robert teaches how to obtain the sizes of the apparent angular diameters (*circuli*) of the Sun (δ_S), Moon (δ_M), and Earth's shadow (δ_T) as functions of the daily velocities of the Sun (v_S) and Moon (v_M),[69] which is done using the following coefficients (ll. 835–853):

$$\delta_S = 11/20\, v_S$$
$$\delta_M = 10/247\, v_M$$
$$\delta_T = 1/60\,(8\, v_M - 25\, v_S).^{70}$$

The diameters will be used to form what Robert calls the *dimidium quantitatum* or "half of the sizes," the sizes in question being the diameters of the eclipsing and eclipsed body. In the Toledan canons 'Cc', the corresponding term is *dimidium utriusque quantitatis*, whereas Hugo Sanctelliensis's translation of Ibn al-Muthannā has *utriusque circuli medietas*.[71] In the case of lunar eclipses, the *dimidium quantitatum* amounts to $(\delta_M + \delta_T)/2$ (ll. 854–856). Its size with respect to the lunar latitude is one of the factors that determine whether or not a lunar eclipse is possible (ll. 870–873). Moreover, the difference the between the lunar latitude and *dimidium quantitatum* is compared to the Moon's diameter to find whether the eclipse is total or partial. The same difference is multiplied by 12 and divided by the lunar diameter to yield digits as an expression of the eclipse's magnitude (ll. 873–888).

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[66] *M*, fols. 44^{v}–45^{r}; cf. *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 33 (ed. Suter 1914: 26–27). The correspondence was already noted by Mercier 1987: 109, 117.

[67] Cc134, 141–142, 163–165 (ed. Pedersen [Fritz] 2002: ii. 640, 644, 656; cf. Pedersen [Fritz] 1992: 51, 53, 60–61); Ibn al-Muthannā, *Commentary on the Tables of al-Khwārizmī*, trans. Hugo Sanctelliensis (ed. Millás Vendrell 1963: 165–173, 189–190).

[68] For further details, see Neugebauer 1962: 57–59, 105–107; Montelle 2011: 222–250.

[69] The use of the velocities for this purpose is acknowledged in the heading accompanying the velocity table from *Lc*14 in *L*, fol. 7^{r}: "Tabula diversi motus Solis et Lune in eadem hora ad sciendum dimidium quantitatum."

[70] The same coefficients are implicit in the tables for the velocities and apparent radii that are transmitted as part of al-Khwārizmī's *zīj*. See Suter 1914: 175–180 (Tab. 61–66); *M*, fols. 39^{r}–41^{r} (Robert's recension); Pedersen (Fritz) 2002: iv. 1415–1416 (JA31).

[71] Cc141, 163 (ed. Pedersen [Fritz] 2002: ii. 644, 656); Ibn al-Muthannā, *Commentary on the Tables of al-Khwārizmī*, trans. Hugo Sanctelliensis (ed. Millás Vendrell 1963: 171, 189).

The definition of the *dimidium quantitatum* will necessarily change where solar eclipses are at stake, seeing as the Earth's shadow plays no role in their genesis. Robert makes no mention of this fact and fails to signal that the value of the *dimidium quantitatum* mentioned in *Lc*18 has changed to $(\delta_S + \delta_M)/2$.[72] According to the 'Indian' rules mentioned above, the lunar latitude used in solar eclipse computations must be adjusted for parallax. The Toledan canons refer to the result of this adjustment as *latitudo lunae ordinata*,[73] whereas Hugo Sanctelliensis's translation of Ibn al-Muthannā describes the same type of latitude as *certissima*.[74] Robert's text uses the strange expression *latitudo occulta* (l. 891), but without explaining the meaning of this term. This lack of context is reflective of the fact that, at least in the extant manuscripts, *Lc*'s account of eclipses bypasses the issue of parallax. Another part of the overall operation that Robert omits completely are the multiple steps one would need to correct the digits of a solar eclipse after their initial approximation.[75] Neither is there any mention of eclipse durations or the beginnings and endpoints of eclipses, even though these could be computed from the parameters already introduced.[76]

One constraint Robert *does* introduce concerns the lunar latitude. According to him, the rules for solar eclipse possibilities change if the Moon's latitude is southern with respect to the ecliptic. If it is northern, eclipses are possible if the Moon is ≤ 12° from the node. If it is southern, this limit diminishes to ≤ 6° (ll. 900–904). Robert gives no reason for this modification, which cannot be found among the Khwārizmīan rules preserved in the Toledan canons. The rationale behind it seems to be the lunar latitudinal parallax, specifically the fact that for northern latitudes the Moon appears deflected towards the south.

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[72] Compare Cc163 (ed. Pedersen [Fritz] 2002: ii. 656).

[73] Cc160–163 (ed. Pedersen [Fritz] 2002: ii. 656).

[74] Ibn al-Muthannā, *Commentary on the Tables of al-Khwārizmī*, trans. Hugo Sanctelliensis (ed. Millás Vendrell 1963: 189).

[75] Cc166–171 (ed. Pedersen [Fritz] 2002: ii. 656–658); Ibn al-Muthannā, *Commentary on the Tables of al-Khwārizmī*, trans. Hugo Sanctelliensis (ed. Millás Vendrell 1963: 190–196).

[76] Cc143–149, 172 (ed. Pedersen [Fritz] 2002: ii. 644–648, 658); Ibn al-Muthannā, *Commentary on the Tables of al-Khwārizmī*, trans. Hugo Sanctelliensis (ed. Millás Vendrell 1963: 173–179, 196–198).

While this effect would indeed justify reducing the southern limit, it would simultaneously call for an expansion of the northern one, which Robert's rule fails to take into account.[77]

*Lc*19–20

As was noted before with respect to *Lc*9–13, the canons for the true longitudes of the five planets are similar to the corresponding paragraphs of the Toledan canons 'Cb', both structurally and in terms of the vocabulary used.[78] Unlike Robert's chapters, these canons take care to point out that Mercury differs slightly from the other planets in how its epicyclic increment is derived from the equation tables. The normal procedure used for the planets is to determine whether the planet is in the apogeal or perigeal half of its deferent, each of which is subject to a separate column in the relevant equation table. In the Toledan canons, these halves are labelled *longitudo longior* and *longitudo propior*, whereas Robert's text (ll. 918–926) and the Tables of London in *L* use *altitudo maior* and *altitudo minor*. The basic instruction given in the canons is to subtract the increment when the planet is at *longitudo longior* (such that the mean centre is 0°–90° or 270°–360°) and to add it when the planet is at *longitudo propior* (mean centre between 90° and 270°).[79] Mercury has a rotating line of apsides, which affects the apparent size of its epicycle and accordingly calls for a different set of rules. Whether to add or subtract the increment is here indicated by explicit instructions inscribed into the column for the 'minutes of proportion' in Mercury's equation table.[80]

Robert's text seems to suggest that such instructions are found in the equation table for every planet, not just Mercury, enabling readers to tell from a mere look at the 'minutes of proportion' whether these were meant to be *minuta diminutionis* or *minuta augmentationis* (ll. 918, 920–921). If this was truly the case in his tables as originally conceived, the equation tables in *L* and *T* must have been transmitted incompletely. In *L*, the only equation table other than that for Mercury to show traces of such instructions is that for Venus, which adds *minue* and *adde* to the column for 'minutes of proportion' (fol. 29^{v}) to indicate the transition from negative to positive increments. The copy in *T* omits these words even from the equation table for Mercury, where they would have been essential.

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[77] According to Ptolemy, the latitudinal eclipse limits for the true Moon in his part of the world are 17;41° north and 8;22° south. See Ptolemy, *Almagest* 6.5 (trans. Toomer 1998: 286).

[78] See Cb145–149 (ed. Pedersen [Fritz] 2002: ii. 438–440).

[79] Cb147 (ed. Pedersen [Fritz] 2002: ii. 438–440).

[80] Cb151 (ed. Pedersen [Fritz] 2002: ii. 440). On the Ptolemaic model for Mercury, see Pedersen (Olaf) 2011: 319–328.

In *S*, the brief chapter on the inferior planets (*Lc*20) is augmented by a substantial amount of text not preserved in any of the other witnesses (see the Appendix below). The addition consists of two parts, both of which address the practical astrological applications of the Tables of London. In the first part, the assumption is made that the reader is interested in computing the positions of the planets for the time of a *quaestio*, which refers to an astrological interrogation. Time measurements made for such astrological purposes would ordinarily have been based on seasonal hours, which is why the first part of the addition in *S* explains how to convert such a measured time into the equinoctial hours employed in astronomical tables. It is probably no coincidence that two sentences added to *Lc*20 in *A* deal with the same issue of time conversion, although their wording bears no immediate resemblance to the addition in *S*.[81]

The second part of the addition addresses the problem of finding the precise time of the vernal equinox as a precondition for computing the *genitura mundi*, that is, the horoscope showing the positions of the planets for the moment when the Sun enters tropical Aries. As an example, the author assumes that the true solar longitude at the beginning of the day in question is found to be 359;57°. The remaining gap of 0;3° is then divided by 148 seconds, which corresponds to the Sun's mean motion per hour according to the Tables of London (0;2,28h). Suspicions that all this material is extraneous to *Lc*20 receive some confirmation from the fact that *A* and *S* both attach to *Lc*23 a passage that uses the same numerical example to address the same problem (see below, p. 330). In *S*, instructions on how to find the time of the vernal equinox are in fact given on three separate occasions, in additions to *Lc*9, *Lc*20, and *Lc*23.

*Lc*21

This very concise set of rules was written for a set of latitude tables in the 'Indian' or Khwārizmīan tradition, whose approach to planetary latitudes differed significantly from the Ptolemaic theory followed by authors such as al-Battānī.[82] In the known versions of the *zīj* of al-Khwārizmī, the latitude tables do not appear as a separate set, but are integrated into the equation tables for the individual planets. They consist of two main components, which in Adelard of Bath's translation are headed *latitudo prima* and *secunda*.[83] This matches Robert's terminology in *La*21 (ll. 951, 954–955, 958, 962–963), which was clearly modelled on the corresponding canon in Adelard of Bath's translation (or his own revision of the same).[84] There is no trace of such columns in the London tables in *L* and *T*, whose equation tables belong to the Ptolemaic tradition. It is worth noting, however, that latitude tables derived from the columns in al-Khwārizmī's equation tables were a common component of the Toledan Tables.[85] They accordingly also feature among the Tables of Marseilles, whose mean-motion tables appear to have been structurally similar to those in the lost first part of the *Liber canonum* (see pp. 216–217 above).[86] This leaves open the possibility that Robert originally included a version of these stand-alone tables in his work.

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[81] See the critical apparatus for l. 947.

[82] See Neugebauer 1962: 34–41; Kennedy and Ukashah 1969; Chabás and Goldstein 2012: 110–112; van Dalen 2018: 106–107.

One of the parameters needed to enter latitude tables of this type is the argument of latitude (*argumentum latitudinis*), which is the distance between the planet and its ascending node. Robert's readers could find the longitude of each planet's ascending node (*locus Draconis*) by consulting the corresponding mean-motion tables, where the required information was written next to or below the longitude of the apogee. Such is the case in *L*, which transmits the same nodal longitudes as the mean-motion tables in the *zīj* of al-Khwārizmī (see Table 10).[87] As with the wording of *Lc*21, Robert of Chester may have taken these longitudes from his own revision of Adelard of Bath's translation.[88] In borrowing them from al-Khwārizmī's *zīj*, he effectively ignored their sidereal character, which strictly speaking made them incompatible with the tropical

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[83] See Tab. 27–56 in Suter 1914: 138–167. For Robert's recension of these tables, see *M*, fols. 12^{r}–14^{r}, 15^{v}–18^{r}, 25^{v}–28^{r}, 29^{v}–32^{r}, 33^{v}–36^{r}.

[84] See *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 17 (ed. Suter 1914: 14). The dependence on c. 17 was already noticed by Mercier 1991: 17. Owing to the incomplete state of the Madrid manuscript of Robert's revision, it is not possible to compare *Lc*21 to his revision of this chapter.

[85] See Cb165–166 (ed. Pedersen [Fritz] 2002: ii. 444–446); Cc313–314 (Pedersen [Fritz] 2002: ii. 716–718); Toomer 1968: 69–70.

[86] Raymond of Marseilles, *Liber cursuum tabularum* 2.15–16 and Tab. 19–20 (ed. Alverny, Burnett, and Poulle 2009: 220–222, 324–335).

[87] See *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 19, Tab. 27–56 (ed. Suter 194: 15, 138–167). These same nodal longitudes were also commonly transmitted alongside the Toledan Tables. See Toomer 1968: 45; Pedersen (Fritz) 2002: iv. 1230–1233 (DC).

[88] See the table headings in *M*, fol. 12^{v}–14^{r} (Jupiter), 15^{v}–18^{r} (Mars), 19^{v} (Venus), 25^{v} (Saturn), 30^{v}–32^{r} (Venus), 33^{v}–36^{r} (Mercury).

TABLE 10 Longitudes of the planetary ascending nodes according to the Tables of London (*L*, fols. 17^{v}, 21^{r}, 24^{v}, 28^{r}, 31^{v})

Saturn	103;12°
Jupiter	82;1°
Mars	21;54°
Venus	59;27°
Mercury	21;10°

apogeal longitudes he had derived from al-Battānī (see pp. 213–215). If Robert recognized this distinction and thought that the nodal longitudes had to be increased in accordance with the rate of precession, he certainly did not say so.

Another instance where Robert imported an element from al-Khwārizmī concerns the headings of columns for the first station in his equation tables, as preserved in *L* and *T* (see p. 208). The first station is here routinely labelled either *statio prima … accedentis* or *statio prima … recedentis*, a distinction which seems out of place in a table or column that was simply there to show a planet's true anomaly at first station. In fact, the terminology in question originated in the latitude columns of al-Khwārizmī's equation tables, where the headings distinguish between the latitude of a planet ascending from a node or descending towards it.[89] In Robert's own recension of these latitude tables, the terms used for this purpose are *accedentis/recedentis* or *accessus/recessus*. For reasons that seem difficult to determine, he decided to transfer this vocabulary to the Battānīan equation tables that accompany his Tables of London, notwithstanding the fact that they contain no columns for latitude. In al-Khwārizmī's *zīj*, the column for *statio prima* always appears immediately to the left of the latitude columns, which may have contributed to this misguided transfer.

All three witnesses to *Lc*21 (manuscripts *ALS*) transmit a textual addition that addresses how to proceed if the value derived from the first table (for *latitudo prima*) is larger than that from the second table (*latitudo secunda*). As found in *L* (fol. 16va), the text reads as follows:

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[89] See n. 83 above. In the earlier Latin translation by Petrus Alfonsi, the terms used are *ascendentis* and *descendentis*. See Neugebauer 1962: 191, 195, 198, 200, 203.

> Quod si contingat secundam latitudinem per primam latitudinem non posse dividi, prima latitudo per secundam dividatur. Quod inde provenerit, latitudo ipsius planete in eadem hora erit, quia maior numerus superponendus est, minor autem supponendus.
>
> But in a case where the second latitude cannot be divided by the first latitude, one must divide the first latitude by the second one. The result will be the latitude of the relevant planet at the moment in question, because the larger number must be placed on top, but the smaller one below.

L is the only one amongst the three witnesses to place this passage where it presumably belongs, which is immediately at the end of *Lc*21. In *S*, the same passage is incongruously wedged into the middle of *Lc*21, appearing after *totum argumentum latitudinis dicendum* (l. 953). The scribe here omitted the final four words, *est … supponendus*, presumably because the similarity between *superponendus* and *supponendus* forced an eye-skip. The scribe of the third manuscript, *A*, added the full passage to the end of the following chapter, *Lc*22, but signalled its connection with *Lc*21 with a note in the margin (*nota de latitudine 5 planetarum*). The natural explanation for the different placements of this passage in the known witnesses would be that it originated in a marginal gloss to *Lc*21, leaving later scribes with the choice of where to insert it.

*Lc*22–23

The purpose of these two chapters is to elucidate the use of the column for the first station (*statio prima*) included in the equation tables for the five planets, which was there to indicate, as a function of the true centre, the arc of true anomaly at which the planet will undergo its first station (see also pp. 173–175). If this amount is subtracted from 360°, the result will be the true anomaly corresponding to the second station (ll. 970–972). To find out whether a planet is direct, stationary, or retrograde at a given time *t*, one compares the true anomaly at *t* with the values corresponding to the first and second station (ll. 972–975). Any difference between these values can subsequently be converted into a time interval by dividing it by the planet's mean motion in anomaly (ll. 978–993). In *Lc*23, this divisor is introduced as the "non-equated motion" of the planet (l. 981: *per motum ipsius planete absque equatione*), which could easily be mistaken for the ordinary mean motion, were it not for the subsequent explanation of how to derive this rate of motion via the diurnal mean motion of the Sun (ll. 994–1003).

The two chapters have close counterparts in the *zīj* of al-Khwārizmī, as revised by Maslama al-Majrīṭī and translated into Latin by Adelard of Bath.[90] In fact, *Lc*22 repeats the corresponding Khwārizmīan canon almost word for word. It seems reasonable to suppose that Robert simply took *Lc*22 from his own revision of Adelard's translation, where the term *coaequatio* regularly replaces Adelard's *examinatio* (for 'equation').[91] Since *M*, the sole witness to Robert's revision, no longer holds the quire in which this canon appeared, this must unfortunately remain an unconfirmed hypothesis.

The second Khwārizmīan canon gives a very general account of how to convert direct and retrograde arcs into time intervals, which does not expressly mention the mean motion in anomaly. Robert's *Lc*23 begins by paraphrasing this canon but then goes on to enrich it with numerical examples and additional information not found in his source. For instance, he lists the relevant rates of mean motion for each of the planets (ll. 999–1000, 1025–1028), which happen to be in complete agreement with what is shown in his Tables of London (in the sub-tables for hours and days):

- Sun: 0;59,8°/d
- Saturn: 0;57,8°/d (= 0;59,8°/d – 0;2°/d)
- Jupiter: 0;54,9°/d (= 0;59,8°/d – 0;4,59°/d)
- Mars: 0;27;41°/d (= 0;59,8° – 0;31,27°)
- Venus: 0;37°/d
- Mercury: 3;6,24°/d

Robert also gives us a worked example where the true anomaly of Saturn at *t* is 1;2,4°, while the anomaly values at first and second station are 0;1,2° and 31;2,4,8° (ll. 1004–1024). These values presumably were not meant to be realistic, seeing as Robert's own equation table puts Saturn's anomaly at first station between 112;44° and 115;30° (*L*, fols. 18^{r}–20^{v}). For the second station, the implied values would be 247;16° to 244;30°. Using his hypothetical values, Robert proceeds to compute how much time would have elapsed between first station and *t*. To this end, he divides the difference of 1;1,2° (= 1;2,4° – 0;1,2°) by Saturn's daily mean motion in anomaly, which is 0;57,8°. The result is one day with a remainder of 0;3,54° or 234 seconds of arc. Robert proceeds to divide these 234 seconds by 148, which he erroneously takes to be the number seconds contained in the hourly motion (ll. 1012–1021). In actual fact, 148 seconds are the correct value for the hourly motion of the Sun according to the Tables of London (0;2,28°), which would have to be lowered by 0;0,5° to obtain the hourly motion in anomaly of Saturn. This mistaken use of 148 seconds does not appear to be a momentary slip, as it is repeated later in the text, where Robert describes the same operation in more general terms (ll. 1028–1033).

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[90] *Ezic Elkaurezmi*, trans. Adelard of Bath, c. 13–14 (ed. Suter 1914: 12–13). The dependence on c. 13 was noticed by Mercier 1991: 17.

[91] See the tabular comparison in Mercier 1987: 117.

In both extant copies of *Lc*23 (*AS*), the information that the division will have to be iterated to find the minutes contained in the time interval (ll. 1019–1021, 1033–1036) is repeated twice. Only the first of these passages is likely to be original to Robert's text. It is in fact striking that the second passage begins with the same words (*Sed tacendum non est quod …*) as an addition to *Lc*20 that is exclusive to *S* (see the Appendix below). The latter closes with an explanation of how to use the rule of division by 148 seconds to find the time of the vernal equinox. An equivalent passage concludes the addition to *Lc*23 in *A* and *S*. In both these added passages, the purpose of finding the time of the vernal equinox is expressly stated to be the *genitura mundi* or horoscope of the year. They also both use the same example of a solar longitude of 359;57°, leaving a gap of 0;3°. It must be divided by 148 seconds to yield the hours until the vernal equinox. The result, which is 1;12h, is spelled out only in the text added to *Lc*23 (see the Appendix below).

*Lc*24

This chapter shows how the computed time of true lunisolar syzygy, as derived using the rules in *Lc*14–15, can be converted into seasonal hours. One reason this conversion was useful from an astronomical perspective was that it made it possible to determine whether a particular solar or lunar eclipse was going to occur during day or night-time, which had obvious consequences for the conditions of its visibility.[92] Given the obvious connection with the contents of *Lc*14–15 (on true syzygy) and *Lc*16–18 (on eclipses), the placement of *Lc*24 in the two extant witnesses (*AS*) seems rather awkward, raising the possibility that this chapter originally appeared elsewhere in the text.

The instructions in *Lc*24 tacitly assume that we have already determined the seasonal length of day and night for the date of the syzygy in question. A common source for this information were tables for oblique ascensions at a given latitude, which usually included columns showing the length of daylight in time-degrees.[93] This style of displaying time as degrees matches the conversion rules in *Lc*24, which require us to convert the known time in equinoctial hours, counted from noon, into degrees by counting 15° per hour. If the result of this conversion exceeds the degrees contained in 6 seasonal daylight hours, these hours must be subtracted from the total. The remainder is divided by the degrees contained in an hour of night-time (ll. 1046–1050). Where the result is less than six seasonal daylight hours, the division must be made using hours of daylight (ll. 1052–1056, 1067–1073).

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[92] This is the context for the parallel instructions in Cc155–159 (ed. Pedersen [Fritz] 2002: ii. 652–654).

[93] Pedersen (Fritz) 2002: iii. 996–1075 (BD–BG).

*Lc*25

This is a very general explanation of how to infer the time of conjunction of two planets from their true longitudes at t. The procedure is analogous to that for finding the time of true syzygy, which was the subject of *Lc*14–15. In both instances, the parameters required are the hourly velocities of the two bodies in question as well as the amount of the *interstitium* between their true longitudes. In *Lc*14 (ll. 750–754), Robert's approach had been simply to subtract the slower velocity from the faster one and use the result as a divisor for the *interstitium*. The time difference Δt between t and syzygy is accordingly found via $\Delta t = \frac{\eta}{vf - vs}$, where η is the *interstitium*, vs is the velocity of the slower planet, and vf is the velocity of the faster planet.

*Lc*25 takes an alternative route of eliminating one of the velocities in favour of a coefficient representing the ratio between them. In the case of the Sun and Moon, a popular approach was to leave out the velocity of the Sun (vs) and instead compute the time interval on the basis of the relation $\Delta t = \frac{13\eta}{12vm}$, where vm is the hourly velocity of the Moon.[94] This relation was based on the assumption that $vm = 13vs$, which implies that during Δt the Moon covers a distance of $\eta + 1/12\,\eta$. It was, of course, possible to use the same principle to restrict the calculation to the velocity of the Sun: $\Delta t = \frac{\eta}{12vs}$.[95] The instructions in *Lc*25 adopt the latter model, in that they use the slower planet (*planeta tardior*) as the divisor for the *interstitium*. To do so, the *interstitium* must first be divided "according to the ratio between their paths" or "circles" (l. 1080: *iuxta eorundum circulorum proportionem*), which here presumably refers to the ratio between the velocities of the two planets. The appearance of the term *circulus* in this context may seem slightly confusing, especially given its earlier use, in *Lc*16–18, to denote the diameters of the Sun, Moon, and Earth's shadow.

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[94] See n. 61 above.

[95] This possibility is mentioned in Raymond of Marseilles, *Liber cursuum planetarum* 2.21b (ed. Alverny, Burnett, and Poulle 2009: 228): "[…] vel divide duodecimam tantum per motum solis in una hora."

It may be worth noting that *Lc*25 is the only chapter in this text to apply the adjective *levis* ('light') in describing a planet, specifically one that moves faster with respect to another (ll. 1075, 1084). Robert probably inherited this usage from Abū Maʿshar's *Great Introduction to Astrology*, where *khafīf* (خفيف), meaning 'light' or 'thin', is used in precisely this fashion.[96] The term is rendered as *levis* in both of the extant twelfth-century Latin translations of the *Great Introduction*, by John of Seville (1133[?]) and Hermann of Carinthia (1140).[97]

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[96] Abū Maʿshar, *The Great Introduction to Astrology* 7.5.4–9, 15, 18, 26–28b (ed. and trans. Yamamoto and Burnett 2019: 764–771, 776–777, 780–783).

[97] Abū Maʿshar, *Liber introductorii maioris ad scientiam judiciorum astrorum* 7.5, trans. John of Seville (ed. Lemay 1995–1996: v. 293–296, 299–302); trans. Hermann of Carinthia (ed. Lemay 1995–1996: viii.136–139). See also the Latin translation of the *Picatrix* 2.6 (ed. Pingree 1986: 55, ll. 15–32).

APPENDIX

Additions to the Text in *A* and *S*

Addition to *Lc*9 (*S*, fol. 91^{v})

Cum in anni revolutione Solem equaveris et plus quam XII signa, ut sunt 20 minuta, inveneris, illa 20 minuta in 60 multiplicabis fientque secunda, que, cum per 148 diversis, horas illorum minutorum optinebis. Residuum vero secundorum, si fuerit, ipsum in 60 multiplica et quod inde provenerit per 148 dividito. Has igitur horas et minuta ex horis cum quibus intrasti diminue ut horam ⟨et⟩ minutum certissimum introitus Solis in Arietem optineas. Similiter, si in Solis equatione minus quam 12 signa minuta et secunda habueris, ex eis predicta ratione horas et minuta constitue, quas videlicet, si horis et minutis cum quibus intrasti addideris, horam et minutum introitus Solis in Arietem habebis.

Addition to *Lc*11 (*S*, fol. 91^{v})

Quod autem iuxta proportionem minutorum proportionalium ad 60 ex coequatione diversitatis diametri circuli brevis argumenti equationi adicitur vel quod tota illa coequatio in minuta proportionalia ducitur productumque per 40 [*sic*] dividitur quodque ex divisione provenit argumenti coequationi adiungitur, hoc ideo fit quoniam datis tribus numeris inequalibus, si maior in minorem ducitur productumque per medium dividitur, quota pars minor numerus medii exstiterit, tota pars maioris ex divisione exibit.

Addition to *Lc*20 (*S*, fol. 94^{r})

Sed tacendum non est quod, cum lector ad coequationem planetarum accesserit, si in die vel nocte horarum inequalium questio inciderit, quotquot hore a meridie diei precedentis in horam questionis et eius partes transierint intuendum erit. Quas cum lector computando invenerit, ipsas in horas equales convertat, ut videlicet quot hore equales in totidem horis inequalibus habeamur diligenter agnoscat, ut per earum numerum et minutorum ipsas sequentium, si qua fuerint, in tabulas canonum certa fiat ingressio. Hore namque omnium canonum in ipsis canonibus equales signantur.

Sed qualiter earum fiat conversio hac ratione colligitur. Si igitur in prefatis horis hore diurne et nocturne simul occurerint, hore quidem diurne in numerum graduum unius hore eiusdem diei precedentis horeque nocturne in numerum graduum unius hore eiusdem noctis precedentis semotim ducantur. Quibus dissolutis utrique gradus simul iungantur. Idem totum per numerum graduum unius hore equalis, id est per 15, dividatur. Quot enim quindene inde provenerint, totidem hore equales ex prefatis horis inequalibus necessario provenient. Quod si post divisionem aliquot gradus superfuerint, ipsa quidem in 4 ducantur, ut videlicet ex ipsis minuta fiant. Cum quibus etiam in tabulas canonum intrandum erit.

Quod si lector mundi genituram tractaverit Solemque circulum zodiacum non perfecisse invenerit, loco Solis iam reperto ipsoque signis 12 subtracto reliquum quod fuerit in secunda dissolvat, ut ex eis horas et minuta quibus Sol eius ambitum perfecerit evidenter agnoscat. Exempli gratia: locus Solis signorum 11, graduum 29, minutorum 57 reperitur, que videlicet, si tu subtraheris, tria remanebunt minuta. Hoc igitur in 60 ducito fientque secunda, que per 148 divisa unam horam constituent. Reliquum vero in 60 ductum et per 148 divisum minuta hore constituent. Hanc igitur horam cum his minutis horis et minutis prime coequationis adice, ut horarum geniture mundi hora introitus Solis in primum minutum signi Arietis certissime invenias.

Addition to *Lc*23 (*A*, fol. 18$^{\text{va}}$–b; *S*, fol. 95$^{\text{r}}$)

Sed tacendum non est quod post divisionem residui argumenti per motum diurnum planete, si residuum divisionis minus CXLVIII secundis extiterit, ipsum quidem residuum in LX ducatur et summa ductionis per CXLVIII partiatur. Quicquid enim inde provenerit, hore minuta monstrabit.

Similiter, si annualem mundi genituram tractaveris et Solem ambitum suum annualem nondum perfecisse inveneris, tunc, si cum eo quod deest idem feceris, temporis spatium quo Sol id ipsum perfecerit optinebis. Ut si in Solis coequatione ad mundi genituram ipsum eius ambitum annualem preter tria minuta perfecisse inveneris, ipsa quidem tria minuta in LX ducito, CLXXX inde colligito. Que videlicet, cum per CXLVIII diviseris, horam unam optinebis. Huius ergo divisionis residuum, id est XXXII secunda, si in LX duxeris et summam, id est mille nongenta XX, per centum XLVIII diviseris, XII minuta, id est quintam partem unius hore aggregabis. Hec

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24 hac] ac *S* 27 precedentis] precedenti *S* 29 provenerint] provenerit *S* 39 60] 40 *S* 44 CXLVIII] 148 *S* 45 LX] 60 *S* ‖ CXLVIII] 148 *S* 48 quod deest] quid est *A* 49 temporis] temperas *A* ‖ perfecerit] pervenerit *A* 51 LX] 60 *S* ‖ CLXXX] 180 *S* 52 CXLVIII] 148 *S* 53 id est] *om. A* 54 id … partem] *om. A*

igitur minuta cum hora prius inventa, si horis et minutis coequationis Solis addideris, horam eiusque partem, qua scilicet horoscopus mundi emergit, certissimam obtinebis.

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